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THE CHANCE OF COLLISION WITH A COMET, IRON METEORITES AND COON BUTTE.

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FOR POPULAR ASTRONOMY.

In a general discussion of comets, we not infrequently hear the question raised as to the likelihood and possible results of a collision with our Earth. The general impression seems to be that such an event is not at all likely to occur, but that if it did the result would be most disastrous. Young in his General Astronomy quotes Babinet, who thought a collision was likely to take place once in about 15,000,000 years. The matter is very simply computed, but we must first define our terms. By a comet we mean a visible comet, that is to say one shining by its own light.

By a collision we shall mean first that any part of the Earth strikes any part of the comet's head, and second that any part of the Earth strikes the most condensed point in the head, which we will call the core, as distinguished from the larger nucleus. What the average size of a visible comet's head may be we have no accurate means of knowing. Young estimates that for a telescopic comet it averages from 40,000 to 100,000 miles in diameter. The diameter of the head of the great comet of 1811 was 1,200,000 miles, that of Holmes' comet in 1892, 700,000 miles, and for naked eye comets generally over 100,000 miles. Let us, however, take the mean of the telescopic comets, and call the average diameter of the head 70,000 miles. In the first case then the comet's core must pass within 39,000 miles of the Earth's center, and in the second case within 4,000 miles. The first case is therefore 95 times more likely to occur than the second.

Calling the distance of the Sun 9.3×10^7 miles, the area of the sphere constructed on the Earth's orbit as a great circle, divided by the area of a great circle of the Earth is

$\frac{4\times 9.3^2\times 10^{14}}{4^2\times 10^6} = 21.6\times 10^8$. Therefore, the core of one comet in every 2,160,000,000 would strike the Earth if they all proceeded directly towards the Sun. The mean perihelion distance of those comets which penetrate the sphere of the Earth's orbit is 0.612, but grouping together those comets whose perihelion distances are about the same, and computing for each group separately the area of the surface of the sphere intercepted by it, we find that the mean surface is about twice as great as if the comet entered it normally. Therefore, the core of one comet in about 100,000,000 will strike the Earth.

In the last half of the last century 121 comets including returns, penetrated the sphere of the Earth's orbit. Therefore, we should expect to be struck by the core of a visible comet once in about 400,000,000 years, and by some portion of the head once in 4,000,000 years. Since comets' orbits are more thickly distributed near the ecliptic than in other regions of the sphere, the collisions will occur rather more frequently than this, but hardly as often as once in 2,000,000 years.

Since it has been estimated that animal life has existed upon the Earth for about 100,000,000 years, a considerable number of collisions, perhaps as many as fifty, must have taken place during that interval, evidently without producing any very serious results.

But besides the visible comets, there are doubtless very many others that are invisible to us. Some of these are large, but happen to be unfavorably situated for observation owing to moonlight or other causes, some are too small to be seen, while other have ceased to be self-luminous.

In this latter class must be included a very large number belonging to Jupiter's family, whose orbits lie near the ecliptic and which have not yet fully disintegrated. These we must meet more frequently than the others because they are constantly returning to perihelion. Whether we are in the habit of encountering the invisible comets ten times or one hundred times as often as those that are visible to us we have no means of knowing. Perhaps the latter figure is the more probable, since comets that are in the process of disintegration become gradually lengthened out until what were originally their heads finally become distributed throughout their entire orbits. Here it becomes largely a matter of definition of terms, but an invisible comet whose head has become lengthened as much as ten times is perhaps more properly referred to as a meteor swarm. Some

will doubtless define any invisible comet as a meteor swarm. During the great star shower of 1833 we must have passed pretty close to the core of an invisible comet, and perhaps a similar encounter with the same comet occurred in 902, the so-called "year of stars."

The question may now be raised have we any terrestrial evidence of the actual collision of the Earth with a comet? In the May number, page 273 of POPULAR ASTRONOMY, it was shown that there is reason to believe that the stony meteorites are of terrestrial origin, having been formed at the time of the birth of the Moon, while the iron meteorites are associated with falling stars, and therefore with comets. In a paper by O. C. Farrington on the Geographical Distribution of Meteorites published in *Popular Science Monthly* of 1904, Vol. 64, page 351, there is a map of the world showing the location of the various places where meteorites have been found. Nearly all have come from the eastern and central United States, Northern Mexico, western and central Europe and India. The area in the eastern hemisphere is perhaps three or four times as large as that in western.

Dr. Farrington states that in the western hemisphere 74 stony and 182 iron meteorites have been found. In the eastern hemisphere there were 299 stony and 79 iron meteorites. With about four times the area, we find four times the number of stony meteorites in the eastern hemisphere, which is what we should naturally expect. If the distribution of the two kinds of meteorites were in the same proportion, and if 79 iron meteorites fell in the eastern hemisphere, then we should expect to find 19.6 in the western. Instead of this, we find 182, or more than nine times as many.

If the iron meteorites had been uniformly distributed in time, so that a few fell each year, it is impossible that such a marked preference for one hemisphere should exist. If, however, most of them fell upon the same day, within a few hours, or minutes of one another, as the result of the collision of a comet with our Earth, we can see at once how this irregular distribution in location might occur.

The date of fall of only ten iron meteorites has been recorded. These are arranged in the following table according to months. Only the year of fall of the last meteorite is known. The weight in kilograms is given in the last column. Seven of these bodies were found in the eastern hemisphere and but three in the western.

IRON METEORITES

Date	Year	Locality	Weight
Jan. 23	1870	Nedagollah, India	4.5
Mar. 27	1886	Johnson Co., Arkansas	47
Apr. 20	1876	Rowton, England	3.5
May 26	1751	Agram, Bohemia	48
June 15	1900	N'gourema, Sudan	—
July 14	1847	Brawnau, Bohemia	24 and 17
Aug. 1	1835	Dickson Co., Tennessee	3.5
Aug. 1	1898	Quessa, Spain	—
Nov. 27	1885	Mazapil, Mexico	4.0
— —	1863	Nejid, Arabia	59

We all know how surely, as shown by archeological researches, not merely small objects, but even large buildings, when abandoned, become covered by the soil, in the passage of the centuries. This applies to fertile as well as to desert countries, and is due partly to the wind, and partly to vegetation. Since all the iron meteorites are found on the surface of the ground, or only in part buried beneath it, they must all have fallen at a comparatively recent date, while doubtless very many more lie at but a short distance beneath the surface. The cometary collision must therefore have been a recent one.

If the core of a comet had struck the western hemisphere of our Earth, it would be much more likely to have fallen into the sea than upon dry land, since the land area is so much the smaller of the two. Nevertheless, there is a very remarkable feature of our continent, that is without its parallel elsewhere in the world. Reference is here made to the elevation known as Coon Butte in northern Arizona. This formation is unfortunate in its name, since it is not a butte, nor are there any raccoons in its vicinity. It has within the past few years been investigated very carefully by Messrs. D. M. Barringer and B. C. Tilghman. These gentlemen have sunk shafts and drill holes in its interior, and dug trenches upon its outer slopes, and have published a monograph giving the results of their investigations in the *Proc. Acad. Nat. Sci.* of Philadelphia, 1905, 861. A further publication by Dr. G. P. Merrill, with numerous excellent illustrations is contained in the Smithsonian Miscellaneous Collections 1908, Vol. 4, 461. The geological statements which follow are summarized from these two papers.

The geological formation of the region is fortunately very simple, and consists of horizontal undisturbed layers of sedimentary rocks, white sandstone being overlaid by yellow limestone, and finally by a thin layer of red sandstone occurring in

isolated localities. The thickness of these layers for 1,000 feet or more is known, owing to the presence of the Cañon Diabolo in the immediate vicinity, of a driven well at Winona ten miles distant, and finally of the Grand Cañon of the Colorado and its branches seventy to eighty miles away.

In the midst of an open plain there lies a round gently sloping hill 150 feet in height, containing a crater with precipitous walls, three-quarters of a mile in diameter, and 600 feet in depth. The walls are composed of broken fragments of the upper layer of the stratified rocks, and no igneous rocks nor any volcanic formations whatever exist within twelve miles of it. Drill holes sunk within the crater show that at the center, at a depth of only 1000 feet, the original strata are undisturbed. It is therefore clearly a surface formation, a pseudo crater, and cannot owe its existence in any way to volcanic forces.

This locality has been known for years as the source of the so-called Cañon Diabolo meteorites. From ten to fifteen tons of these bodies have been exported for commerical purposes. They are of the nickel-iron variety, and contain no stony matter. Those which have been found since Messrs. Barringer and Tilghman took possession of the property, now some 2,000 in number, were arranged in a crescent, situated concentrically with regard to the crater, and extending to an extreme distance from it of two and a half miles. Recently considerable quantities of so-called "iron shale" have been found. This consists chiefly of the oxides of iron and nickel. It sometimes occurs in spherical masses several inches in diameter, and often at the center is a piece of meteoric iron. Its distribution is similar to that of the other irons.

Beneath the floor of the crater are found enormous deposits of nearly pure silica, in an extraordinarily finely divided state. Although under a microscope the particles are seen to be sharp and angular, they are so fine as to be invisible under an ordinary lens and to give no feeling of grit when taken between the teeth. Such material cannot be produced by ordinary erosion, and can only be due to the shattering of the substance by a sudden blow. Mixed with this silica has been found meteoric material extending to a depth of 900 feet below the level of the original plain. It is therefore evident that the formation of the crater and the deposition of the meteoric material took place at the same time.

The meteoric deposits lie to the northeast of the crater, hence we should naturally suppose that the great mass came original-

ly from that direction, the smaller pieces suffering greater resistance from the air, and therefore falling behind it. It has been shown that this great body must have been broken into many pieces by the shock of the collision, otherwise it would have made its presence felt in the magnetic survey conducted for the purpose of its detection by Professor Gilbert of the Geological Survey. At least three bore holes out of five sunk near the center of the crater have struck what appear to be large pieces of meteoric iron, at depths of from 700 to 900 feet below the level of the surrounding plain.

Artillery experiments have shown that solid round shot, traveling at about 1,800 feet per second will penetrate sandstone for two diameters of the shot, making a crater-like cavity, before the iron ball is shattered in pieces. If this rule is applied to the great meteoric mass in question, we should expect its original diameter to have been about 450 feet. Without doubt it was moving at a much higher speed than the cannon balls, which would imply a smaller body, but on the other hand it was probably relatively more fragile, on account of its greater size. We cannot consider the above estimate, then as anything more than a rough approximation.

The only serious objection to the theory of a collision with a great meteorite is the lack of evidence of a high temperature. That the irons and iron shales have been heated is obvious, and also it is clear that a relatively small amount of quartz has been softened by heat, but why great masses of quartz, formerly in a liquid state have not been discovered seems inexplicable, unless the meteorite was really moving at a comparatively slow speed. Possibly some specimens will be found lying beneath its broken fragments, when these latter are uncovered.

The nucleus of the head of a comet must not be thought of as a solid body. In some comets the nucleus is a large object. In that of 1845 III it measured 8,000 miles in diameter, and in that of 1858 VI it measured 6,000 miles. The nucleus is merely the brightest portion of the gaseous atmosphere by which alone the head is made visible. In some cases it is granulated like a star cluster, in most comets there is no nucleus at all. It is probable that in general the head consists of a number of large meteorites surrounded by many smaller ones. If the comet is a visible one, each of these meteorites is surrounded by its own atmosphere. If the comet is invisible, the meteorites are still there, by they have lost their atmospheric envelopes.

If the Earth traversed the head of a comet at the time that

Coon Butte was formed, we must not consider the great meteorite that we have been discussing necessarily to have been its core. This meteorite may have been only one out of many, some perhaps much larger than itself. Many of these huge bodies may have escaped the Earth altogether, while others perhaps lie buried in the Pacific, which is distant from Coon Butte by only about 400 miles.

If merely a coincidence, it is certainly surprising, considering the total extent of the land surface of our globe, that of the world's ten largest meteorites, seven should have fallen within 900 miles of Coon Butte. In the following list each meteorite is followed by its weight in tons and its distance in miles. All are of the nickel iron class.

Locality	Weight	Distance
Anighita, Cape York, Greenland	38	3000
Bacubirita, Sinaloa, Mexico	20	650
Chupaderos, Chihuahua, Mexico	16	600
Williamette, Clackamas Co., Oregon	16	900
San Gregorio, Chihuahua, Mexico	11	600
Bemdigo, Bahia, Brazil	5	—
Cañon Diabolo, Coconino Co., Arizona	4	0
Cranbourne, Melbourne, Australia	4	—
Concepcion, Chihuahua, Mexico	3	650
Rio Florida, Chihuahua, Mexico	3	650

It is said that a large iron meteorite weighing twelve tons has recently been discovered somewhere in the state of Washington. Its distance from Coon Butte is therefore about 1,100 miles.

The Chupaderos, San Gregorio, Concepcion, and Rio Florida meteorites all lay within one hundred miles of one another, and Professor J. L. Smith has suggested, *American Journal Science*, 1871, Vol. 102, 338, that they are all parts of one fall. It is suggested in this paper that nine out of the ten, including the Bemdigo meteorite might have fallen at the same time, since this last is located only 80° distant from Coon Butte, measured on the arc of a great circle. The Cranbourne meteorite, however, is clearly on the other side of the globe, and hence must have fallen at another date. A better idea of the size of these bodies may be obtained if we give the dimensions of three of the larger ones in feet. The Anighita meteorite measures $13\times6\times5$ feet. The Bacubirita the same, and the Williamette $10\times7\times4$. The fact that none of these great bodies penetrated the soil to any great extent, or crushed the rocks upon which it fell, indicates that they must have been moving comparatively slowly.

Had they been in the form of round shot, moving at a speed

of 1,800 feet per second, we should have expected them, as we have already seen, to have buried themselves even in sandstone to a depth of two diameters, and then to have broken in pieces. In the case of the Bacubirita and Williamette meteorites, they buried themselves instead in soft ground to a depth of one diameter. The former then brought up on a ledge of rock, but was neither fractured nor seriously defaced. No statement is made by Ward in his paper regarding the nature of the ground beneath the Williamette meteorite. All the other Mexican meteorites have been removed from the spots where they originally fell, so that no information is now available with regard to their original velocities. The mere fact that they were found at all, implies, however, that they probably had not sunk more than one diameter into the ground.

That meteorites sometimes have considerable penetrative force is shown by the case of the one that fell at Knyahinya, Hungary, which buried itself in the soil to a depth of eleven feet, or between three and four of its diameters, before it fractured. The soil beneath it was found compressed to a stony hardness. This meteorite weighed 660 pounds or only about one tenth part as much as the smallest of the ten great iron ones. Moreover, this one was of stone, and so had but one third the specific gravity of the others, from which we conclude that they were moving at a comparatively low speed. This is further corroborated by the fact that the iron meteorite that fell at Agram, Bohemia, in 1751, although but 100 pounds in weight, buried itself to a depth of fifteen feet. The similar meteorite, of nearly identical weight, which fell at Cabin Creek, Johnson Co., Arkansas, in 1886 buried itself to a depth of three feet or about twice its largest dimension. The first of these was broken in two, the other was unfractured.

Considering the velocity with which all meteors enter our atmosphere, it is certainly a matter of surprise that the speed with which they reach the ground should be so leisurely. A meteorite falling vertically encounters no more gaseous molecules than a cannon ball that has traversed five miles of air at the sea level. Yet a modern projectile at the end of five miles is clearly moving much faster than any iron meteorite whose effects have hitherto been recorded. The cause of this extreme retardation is probably the resistance of our atmosphere, not to the meteorite itself, but rather to the atmosphere of the meteorite, which latter is constantly being generated by evaporation of the metal or stone in quantities proportional to the exposed surface.

The extraordinarily slow speed which we concluded was possessed by the great meteorite of Coon Butte, seems to have been also characteristic of the large iron meteorites that we have associated with it, as well as with the majority of the smaller iron meteorites that fell in prehistoric times, and that are now found upon the surface of the ground. If all originated from the same comet, then this slow speed indicates that the comet and the Earth were moving in the same direction, and since the comet was near perihelion, it must have been moving the faster of the two and, therefore, overtook the Earth. The falls therefore occurred between noon and midnight.

Mr. Tilghman thinks from geological appearances that the collision at Coon Butte certainly occurred within 5,000 years, while stunted cedars growing on the rim of the crater show from their rings of annual growth, that the event must have taken place at least 700 years ago. From the consideration already adverted to, that such an excess of iron meteorites, which we suppose to have fallen at the same time, are still found lying on the surface of the ground, all over the American continent, it would appear that the lesser figure is much more likely to be correct than the larger one.

The civilized nations of those days were all on the other side of the globe, with China in full daylight, and Europe in the early morning hours. We can expect no testimony from them therefore that will be of value, unless indeed we accept the rather indefinite statement quoted by Chambers in his Handbook of Astronomy 1889, 616, that in some Eastern Annals of Cairo it is related that in August, 1029, "many stars passed with a great noise and brilliant light." Cairo is about 100° distant from Coon Butte, measured upon a great circle, so that if the radiant was near the zenith in Arizona, meteors might have traversed the sky tangent to the Earth's surface at Cairo. If the event described refers to a meteoric shower, as the phrase "many stars" would seem to imply, it was certainly unique in occurring with "a great noise." During the splendid show of Leonids in 1833, one of the most impressive features was said to be the deathlike silence that prevailed. The loud noise would imply that the meteors closely approached the Earth's surface where the atmosphere is dense, which would mean that they were moving slowly relatively to the Earth. Regarding the date, August 1029, it is of interest to note that of the ten iron meteorites whose dates of fall are known, two should have fallen upon August 1.

A fact which should not be overlooked in this connection is that the great Mexican meteorites were considered holy by the Indians, in the time of the Spanish invasion. Indeed, some of them had already been removed from their original resting places, before the coming of the Spaniards. This would seem to imply a knowledge of their celestial origin, and to furnish an indication of their comparatively recent fall. A similar attention was paid to the palladium of Troy, to the image of Diana at Ephesus, and to the sacred shield of Numa, all of which were said to have fallen from heaven, and were doubtless really meteorites.

There appear to be neither Mexican nor Indian traditions that the heavens at any time appeared to be on fire with falling stars. There appears to have been no wide spread catastrophe due to asphyxiating gases, such as might be indicated by scattered human and animal skeletons. Altogether no particular harm seems to have been done by the collision excepting at the immediate point where the great meteorite struck.

Although we are not able to identify the comet which may have caused this collision, there is one fact given by Barringer and Tilghman that should not be overlooked. This is the statement that the meteorite clearly came from some point to the north of the zenith. The latitude of Coon Butte is $+36°$, therefore, the radiant of the comet must lie appreciably north of this declination. This eliminates eight-tenths of all the comets known. Of the few whose orbits at the present day nearly intersect that of the Earth, as indicated by their associated meteor showers, we are thus able to eliminate those associated with the Lyrids and the Leonids. The radiant of the Perseids is in declination $+57°$, but these meteors although coming in August, as described in the Annals of Cairo, move altogether too fast ever to reach the Earth's surface, and a slow speed is definitely indicated by the great meteorites already mentioned.

The radiant of the Andromedids is in declination $+44°$, or $8°$ north of the latitude of Coon Butte. One iron meteorite apparently connected with this swarm did actually reach the ground at Mazapil in northern Mexico in 1885 during a shower of Andromedids. A most interesting account of this event by W. E. Hidden is given in the *American Journal of Science* 1887, Vol. 135, 221. These meteors are connected with Biela's comet, a companion of which, as computed by Klinkerfues and observed by Pogson, perhaps touched the Earth in 1872. The Andromedids, however, encounter the

Earth at a speed of eleven miles a second, which seems much too high as compared with that of the great meteorites. The Mazapil meteorite for example penetrated the ground to a depth of twelve inches or two diameters, although weighing only ten pounds. Moreover, the date of this swarm, which falls in November, is inconsistent with the observations made at Cairo. These observations, however, are too indefinite to carry much weight, and the date obtained from them can be looked on merely as a suggestion.

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April 14, 1909.

ON THE NATURE AND POSSIBLE ORIGIN OF THE MILKY WAY.*

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While the milky way has long been recognized as a relatively thin segment of space in which stars appear more numerous than elsewhere no satisfactory explanation has been offered for the existence of such a segment with the Earth apparently at its center, or for any of its characteristic peculiarities of aspect and relationship to the stars as a whole. Noteworthy among the features calling for explanation are the following: The milky way is a belt approximately following a great circle of the sky but broad and diffuse throughout one-half of its course while relatively narrow and well-defined on the opposite side. The broad half of the belt is cleft in two by a dark lane running along its axis and in addition contains numerous rifts and holes from which the narrow half is relatively free. The number of stars per unit area of the sky is a maximum in the milky way and diminishes progressively on either hand while the inverse relation is true for the nebulae, their frequency increasing with increasing distance from the milky way.

It is shown in the present paper that all these peculiarities are immediate results of the supposition that the visible universe consists in the main of two distinct but interpenetrating parts, the first of which is a chaos of indefinite extent in which stars and cosmic dust are distributed with some rough approach to

* Abstract of paper read before the National Academy of Sciences. April, 1909.

uniformity in general, but with a marked tendency to local aggregations and clusterings. Through this chaos moves the second part, a cluster of stars of great but measurable dimensions, long, broad but comparatively thin and including the Sun as one of its central members. The diameter of the cluster is to be measured in hundreds of light years and throughout at least a large part of its central regions the stars are much more densely clustered than in the external chaos.

In accordance with well known dynamical laws this moving star stream would operate much after the fashion of a snow plow, sweeping away the cosmic dust from its path and piling it on either hand, above and below the plane of the cluster. The transparent rift thus formed is the milky way through which we see farther and command a view of more stars than through the intensified dust clouds on either side. The dust ejected toward the poles of the milky way constitutes the substance of the nebulae which there abound.

The narrow half of the milky way is that which lies behind the moving swarm since here we see the accomplished work of ages and look between dust clouds long since produced that converge to a vanishing point. Ahead, in the direction of motion, the work of clearing a path is in progress and relatively near at hand, so that the partially cleared space subtends for us a broader angle, in the midst of which there have collected considerable quantities of primordial dust, the slower moving particles, which have been captured and permanently annexed by the vanguard of the swarm. The annexed dust cloud constitutes the long cleft in the milky way while its attendant holes and rifts mark unfinished work on the inchoate side of the galaxy.

The interpretation of the milky way here offered must not be judged solely by its consonance with the phenomena above suggested. It must harmonize with every other fact known about the milky way and it has been the task of the author to seek widely for discord as well as harmony between such facts and the theory above outlined, making the test wherever possible a quantitative numerical one. No serious discordance has been found but the agreement with knowledge hitherto vaguely (or not at all) correlated with the milky way is in some instances striking. Thus the researches of Kapteyn, Eddington and Dyson upon the proper motions of the stars have shown that in the main these bodies belong to two groups in relative motion along the line and in the direction above suggested in explanation of the milky way. Again Pickering has recently announced

certain well-marked differences in the distribution of stars of different spectral types, viz. The fainter stars of the galaxy are almost wholly of the first (Sirian) spectral type. The number of stars of the first type increases with diminishing brightness in a four-fold ratio for each successive magnitude, as theoretically it should increase if these stars were uniformly distributed through infinite space. Per contra, stars of the second type (Solar) increase from magnitude to magnitude only in a ratio represented by the number 3.25, thus implying a distribution very unlike that of the first type stars. All three of Pickering's propositions together with similar ones earlier formulated by Seeliger for the totality of stars, without distinction of spectral type, are numerically accounted for by the supposition that the stars composing the primitive chaos are mainly of the Sirian type while those of the solar group are predominantly of the solar type. By direct enumeration Eddington finds that this relative predominance of spectral types is shown in the two groups into which the stars are divided with reference to their systematic proper motions.

It is easily seen to be a necessary corollary from our explanation of the milky way that stars in or near the galaxy should on the whole appear to move more slowly across the sky than do similar stars remote from the milky way and that this predicted result is in fact true has been shown by at least two astronomers. Another interesting corollary may be derived through the supposition that a star belonging to the solar group may by virtue of its motion be made to pass so near to one of the Sirian stars as to produce disturbances, one upon the other, that will long remain marked by some peculiarity of spectrum. If such were the case the stars so marked would be found only in or near the milky way and they should be especially numerous and compactly clustered astern of the solar group, they should be more sparsely distributed ahead of it and should be almost completely lacking on either side of the procession. The so-called Orion stars constitute just such a set of objects, marked and distributed as above and presenting the further peculiarities that their apparent motion across the sky is abnormally small and that their number shows no tendency to increase as we pass from the brighter to the fainter magnitudes. All of these characteristics are such as would be possessed by stars formed as above suggested.

In a somewhat similar class are the new or temporary stars believed to result from collisions of some kind and found only

in or near the milky way. Why they are limited to the milky way is not apparent, since that is the region, according to the present hypothesis, in which large relative motions are to be expected.

We may look upon double stars as produced by the close approach of a solar to a sirian star under circumstances such that the gravitational bond between them becomes too strong to be broken and the two bodies abide thenceforth in enforced partnership. The size and shape of the orbits in which they shall move about their common center of gravity are determined by the circumstances of their meeting and an elementary analysis suffices to show that the circumstances that tend to produce a small orbit will equally tend to make that orbit nearly round while those which make a large orbit will equally tend to make it more pronouncedly oval. A statistical examination of double stars shows that they do in fact show this relation among themselves, a small major axis being predominantly associated with a small eccentricity, an agreement between fact and theory that can hardly be accidental.

The test of a valid theory is its power to co-ordinate apparently unrelated facts without coming into conflict with any of them and, in view of the illustrations of such co-ordination given above and of others for which space does not here suffice, there is here presented the concept of a definite group of stars moving through a much more widely extended chaos in the best working hypothesis at present attainable with reference to the stellar system.

RESULTS OF RECENT RESEARCHES ON THE PHYSICAL CONSTITUTION OF THE SUN.*

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In the *Astronomische Nachrichten*, Nos., 3992, 4053, and 4104, 4152, the writer has given a somewhat extended development of the theory of the physical constitution of the heavenly bodies. The theory finally adopted is that, with the exception of the encrusted planets and similar dark bodies among the fixed stars, the heavenly bodies are made up of gaseous matter reduced to

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* *Memorie della Società degli Spectroscopisti italiani*, vol. XXXVII.

the state of single atoms; and the laws of density, temperature, pressure, and rigidity are carefully worked out for this physical state, which may be regarded as the best available approximation to the probable conditions existing in the stellar universe.

As the Sun and stars composing our sidereal system may be assumed to conform closely to these laws, it becomes of great interest to compare these theoretical deductions with the results of observation, especially in the case of our Sun, which is the only star sufficiently close to us to permit of accurate investigation. At the request of Professor Riccò of Catania we propose therefore to summarize the chief conclusions at which we have arrived, and to apply the results to the Sun, in the hope of throwing some additional light upon the unsolved problems of the Physics of the Stars.

It is well-known that while the observation and photography of the Sun have been greatly extended of late years, very little progress has been made in the theory of the Sun, and the extension of this subject is therefore of high interest to all contemporary investigators.

To photograph the outside surface of the Sun, in the hope of deducing the underlying laws of the internal movement, is a good deal like photographing the wave-swept surface of the sea, far from the land, with a view of finding the laws of the tides and other currents of the ocean. For the surface of the Sun is in a state of incessant change, and the instantaneous appearance of the photosphere does not indicate the nature of the movement beneath, any more than the billows of the open sea will disclose the laws of the ocean currents.

It may be assumed that there is some continuity in the phenomena witnessed on the Sun's surface, but the order of events is difficult to establish, because the changes noted cannot be interpreted without an approximate understanding of the underlying physical conditions, which heretofore have been very little studied, owing to the fact that there has been no adequate method for attacking the problem. After we have developed the principles of the monatomic theory, we shall recur to the interpretation of the observed phenomena.

In *A. N.* 3992 we have developed the theory of the internal density and pressure within the principal bodies of the solar system, on the hypothesis that the density conforms to Laplace's celebrated law for the density of the Earth, which naturally is somewhat modified in its application to other masses of differ-

ent physical constitution. While this gives a better approximation to the truth than the simple hypothesis of uniform density, and proves to be satisfactory for the encrusted planets; yet the result is found to be unsatisfactory for the Sun and major planets, which are masses at high temperature, and certainly of small density near the surface, and therefore of correspondingly greater density in their central parts than is indicated by the Laplacean law.

On several grounds it may be held that the monatomic theory, according to which the heavenly bodies are gaseous masses reduced by their enormous temperature to the state of single atoms, gives the closest known approximation to the true condition of the Sun and main body of the fixed stars. If any departure from this simple theory takes place, it will be chiefly in the outer layers, where the physical conditions change rapidly, and entire continuity under the conflict of antagonistic forces can scarcely be expected. In the neighborhood of the photosphere and chromosphere, the fluid is subjected to great velocity of movement, while the force of gravity is such as to produce an abrupt change in the pressure; on the other hand the fall of temperature is exceedingly rapid as the upper limits of the photosphere is approached, and the radiation pressure of the Sun's light is so intense as to largely if not entirely overcome the force of gravity. Under the circumstances the discontinuous physical conditions existing at the Sun's surface necessarily operate to modify the full validity of ordinary physical laws. But while this takes place in the surface layers of the Sun, it can hardly be true in any of the deeper portions of that globe, where there is no sudden transition, as at the boundary of the sphere.

In masses of monatomic gas, the ratio of the specific heat under constant pressure to that under constant volume is $k = 12/3$, while for a gas with biatomic molecules like hydrogen, oxygen, nitrogen and common air, the value of this ratio is $k = 1.4$. In the year 1869 J. Homer Lane showed that the laws of internal density, temperature and pressure are to be determined from the principle of convective equilibrium, or a diabatic circulation. (*American Journal of Science* July, 1870). The relations connecting the density, temperature, and pressure are given by certain equations which we shall now briefly explain.

Let σ denote the density at any point of the Sun's radius, σ_0 the density at the center; T the temperature at any point, and T' the temperature at a point where the density is σ'. Let x be

the distance from the Sun's center, x' the limiting value for x at the boundary of the photosphere, which proves to be $x' = 3{,}653962$; and let μ denote the integral

$$\mu = \int_0^x \left(\frac{\sigma}{\sigma_0}\right) x^2 dx = \frac{m}{4\pi\sigma_0}, \tag{1}$$

where m is the mass included within a sphere of radius x.

Then

$$1 - \left(\frac{\sigma}{\sigma_0}\right)^{k-1} = \int_0^x \frac{\mu dx}{x^2}, \tag{2}$$

which may be solved by successive approximations.

The law of density thus becomes

$$\sigma = \sigma_0 \left\{1 - \int_0^x \frac{dx}{x^2}\int_0^x \right\} 1 - \int_0^x \frac{dx}{x^2}\int_0^x \Big[1 - \int_0^x \frac{dx}{x^2}\int_0^x \Big(1 - \int_0^x \frac{dx}{x^2}\int_0^x \quad . \quad . \quad .$$

$$. \quad . \quad . \quad . \frac{\sigma}{\sigma_0} x^2 dx \,, \quad . \quad . \quad . \quad . \Big)^{\frac{1}{k-1}} x^2 dx \Big]^{\frac{1}{k-1}} x^2 dx \Big\}^{\frac{1}{k-1}} x^2 dx \Big\}^{\frac{1}{k-1}} \quad . \quad . \quad . \tag{3}$$

When the series is thus developed, the value of $\frac{\sigma}{\sigma_0}$ is determined, and the law of density is known; the value of μ may then be found by one additional integration

$$\mu = \int_0^x \frac{\sigma}{\sigma_0} x^2 dx \,. \tag{4}$$

The values of μ and $1 - \left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3}}$ determined by calculation are (cf. *A. N.* 4053 p. 327) as follows:

$$\mu = \frac{x^3}{3} - \frac{x^5}{20} + \frac{x^7}{240} - \frac{x^9}{3888} + \frac{19x^{11}}{1425600} - \frac{2719x^{13}}{4447872000}$$
$$+ \frac{20621x^{15}}{800616960000} - \frac{19328x^{17}}{19054686480000} + \frac{39667364x^{19}}{1042672289218560000}$$
$$- \frac{8078124341x^{21}}{5911918798692357200000} + \quad . \quad . \quad . \quad . \tag{5}$$

$$1 - \left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3}} = \frac{x^2}{6} - \frac{x^4}{80} + \frac{x^6}{1440} - \frac{x^8}{31104} + \frac{19x^{10}}{14256000} - \frac{2719x^{12}}{53374464000}$$
$$+ \frac{20621x^{14}}{11208637440000} - \frac{193328x^{16}}{3048749383680000}$$
$$+ \frac{39667364x^{18}}{1876810120593408000} - \frac{8078124341x^{20}}{11822903759738470400000} + \cdots \tag{6}$$

In these equations x varies between the limits $x = 0$, corresponding to the Sun's center, and $x = x' = 3.653962$, which is the value at the boundary of the photosphere.

When the law of density is thus established the internal distribution of temperature may be calculated from the formula

$$T = T' \left(\frac{\sigma}{\sigma'}\right)^{\frac{2}{3}} \tag{7}$$

in which σ' and T' are the surface density and temperature respectively, and σ and T the density and temperature at any point within the Sun's globe.

Now by the above series (6) we know the value of σ for every point of the Sun's radius, compared to water as a standard, and hence when we fix on values of T' and σ' corresponding to the photosphere, we have the means of determining the internal distribution not only of density but also of temperature. As extreme limits we take $\sigma' = 0.1$ and 0.01 respectively of atmospheric air, under normal pressure at sea level; and we fix the upper and lower limits of the surface temperature at 6000° C and 12000° C. The resulting distributions of density, temperature and pressure are indicated in the following table.

Let the surface gravity of the Sun be denoted by G, and suppose the value of gravity at the surface of any concentric spherical shell of radius x to be G'. Then by the method developed in the paper on the Physical Constitution of the Heavenly Bodies (cf. *A.N.* 4053, section VII equation (τ)) it is shown that

$$\frac{G'}{G} = \frac{3\sigma_0}{x'x^2\sigma_1}\int_0^x \frac{\sigma}{\sigma_0}\, x^2 dx - \frac{3\sigma_0}{x'x^2\sigma_1}\,\mu\,. \tag{8}$$

For a gaseous sphere it is easily shown (cf. *A. N.* 3992, equation (2-3)) that the differential equation for the pressure is

$$dp = -\sigma G' dx\,. \tag{9}$$

In our present work the minus sign may be omitted, as it simply denotes that the pressure is directed toward the origin of co-ordinates at the Sun's center, where $x = 0$.

TABLE SHOWING THE PHYSICAL CONSTITUTION OF THE SUN ACCORDING TO THE MONATOMIC THEORY.

R Radius	$\frac{\sigma}{\sigma_0}$	σ Water = 1	σ Air = 1	$\bar{\omega}$ Atmospheres	T Hypothesis T = minimum $T' = 6000°$ C. $\sigma' = 0.0001293187$	T Hypothesis T = maximum $T' = 12000°$ C. $\sigma' = 0.00001293187$	Rigidity depending on Pressure. Nickel Steel = 1
					°	°	
1.00	0.0000015	0.0000129	0.01	—	6000 C.	12000 C.	—
0.99	0.000651	0.005472	4.233227	54635	72856	676338	0.054635
0.98	0.001864	0.015700	12.140670	316531	144870	1365662	0.316531
0.97	0.003476	0.029286	22.646390	894699	222921	2069413	0.894699
0.96	0.005435	0.045786	35.405630	1884224	300284	2787593	1.884224
0.95	0.007713	0.064975	50.245406	3376805	379212	3520293	3.376805
0.94	0.010296	0.086735	67.070500	5464675	459733	4267780	5.464675
0.93	0.013173	0.110978	85.817600	8240856	541837	5029970	8.240856
0.92	0.016343	0.137680	106.466000	11804019	625593	5807490	11.804019
0.91	0.019799	0.166792	128.681100	16250623	710932	6599703	16.250623
0.90	0.023541	0.198320	153.357800	21636565	797912	7407160	21.636565
0.80	0.077049	0.649096	—	156467430	1758935	16328500	156.467430
0.70	0.161316	1.359001	—	536137160	2878659	26723100	536.137160
0.60	0.276802	2.351913	—	1385551200	4125900	38301450	1318.551200
0.50	0.419776	3.536397	—	2639437700	5446090	50556970	2639.437700
0.40	0.579211	4.879548	—	4513802000	6747892	62660430	4513.802000
0.30	0.737977	6.217069	—	6759055500	7932940	73642880	6759.055500
0.20	0.874463	7.366897	—	8968448000	8883145	82463830	8968.448000
0.10	0.967136	8.147617	—	10607851000	9500156	88191620	10607.851000
0.00	1.000000	8.424480	—	11215403000	9714170	90178370	11215.403000

Substituting for G' its value from (8), namely $G = \frac{3\sigma_0 G\mu}{x' x^2 \sigma_1}$, and integrating, we have

$$p = \int_0^x dp = \int_0^x \frac{3\sigma G \sigma \mu dx}{x' x^2 \sigma_1} = \frac{3\sigma_0^2 G}{x'\sigma_1}\int_0^x \left(\frac{\sigma}{\sigma_0}\right)\frac{dx}{x^2}\,\mu$$

$$= \frac{3\sigma_0^2 G'}{x'\sigma_1}\int_0^x \left(\frac{\sigma}{\sigma_0}\right)\frac{dx}{x^2}\int_0^x \left(\frac{\sigma}{\sigma_0}\right)x^2 dx\,. \qquad (10)$$

The last of these integrals is the series called μ, given above in equation (5).

Using this value in equation (10) we get

$$p = \frac{3\sigma_0^2 G}{x'\sigma_1}\int_0^x \frac{\sigma}{\sigma_0}\frac{dx}{x^2}\left[\frac{x^3}{3} - \frac{x^5}{20} + \frac{x^7}{240} - \frac{x^9}{3888} + \cdots\right] \qquad (11)$$

$$= n\,\frac{3(\sigma_0 g)^2}{x'(\sigma_1 g)}\int_0^x \frac{\sigma}{\sigma_0}\left[\frac{x}{3} - \frac{x^3}{20} + \frac{x^5}{240} - \frac{x^7}{3888} + \cdots\right] dx \qquad (12)$$

where $n = \frac{G}{g}$ (cf. *A. N.* 4104, pp, 382-383).

This equation gives the pressure at any point of the Sun's radius, on the hypothesis that the whole mass is composed of gases reduced to the state of single atoms.

To determine the pressure throughout the Sun's globe, we shall use this equation, which involves the series $\frac{\mu}{x^3}$.

For the pressure on any layer of the Sun's globe depends upon the law of density of the superincumbent matter, the accumulated weight of which is sustained by the reaction of the enclosed nucleus.

Now

$$\mu = \frac{x^3}{3} - \frac{x^5}{2^2 . 5} + \frac{x^7}{2^4 . 3 . 5} - \frac{x^9}{2^4 . 3^5} + \frac{19x^{11}}{2^6 . 3^4 . 5^2 . 11} - \frac{2719x^{13}}{2^{10} . 3^5 . 5^3 . 11 . 13}$$

$$+ \frac{20621x^{15}}{2^{10} . 3^5 . 5^3 . 11 . 12 . 13 . 15} - \frac{193328x^{17}}{2^{10} . 3^5 . 5^3 . 11 . 12 . 13 . 14 . 15 . 17}$$

$$+ \frac{39667364x^{19}}{2^{11} . 3^7 5^3 . 11 . 12 . 13 . 14 . 15 . 16 . 17 . 19}$$

$$- \frac{80781243 41x^{21}}{2^{11} . 3^8 . 5^4 . 11 . 12 . 13 . 14 . 15 . 16 . 17 . 18 . 19 . 21} + \cdots \qquad (13)$$

Determining the coefficients of this equation, and integrating the expression

$$\int_0^x \frac{\sigma}{\sigma_0}\left[\frac{x}{3}-\frac{x^3}{20}+\frac{x^5}{240}-\frac{x^7}{3888}+\cdots\right]dx \qquad (14)$$

in the form of the product of two series, the evaluation of a square of 625 elements, about 400 of which are sensible in the eighth place of decimals, when $x = x' = 3{,}653962$, gives for the integral the value

$$I = 0.0394230\ . \qquad (15)$$

The expression for the pressure at the Sun's center, when the density is supposed to follow the monatomic law of distribution, is

$$\bar{\omega}_0 = n\frac{3(\sigma_0 g)^2 x' I}{(\sigma_1 g)10333} = 11215403000 \text{ atmospheres}\ . \qquad (16)$$

The pressure at any point of the radius is now easily found from the expression

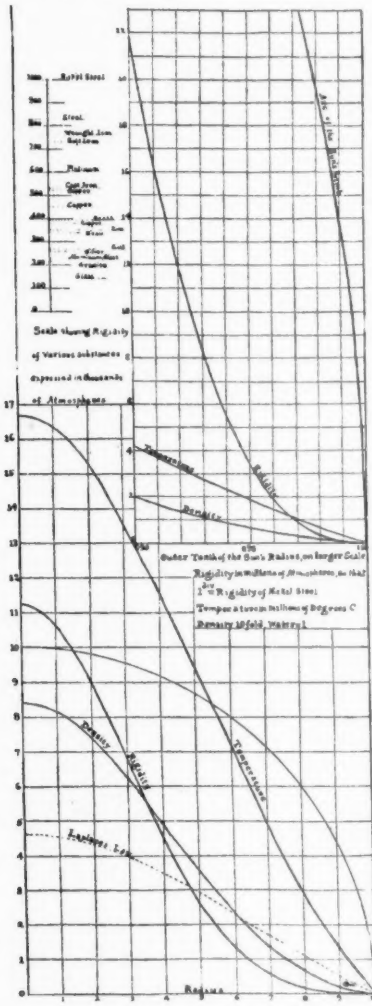
$$\bar{\omega} = \bar{\omega}_0\left(\frac{\sigma}{\sigma_0}\right)^{12/3}, \qquad (17)$$

the results of which are already given in the above table.

In regard to the significance of these, it suffices to point out that above the critical temperature gaseous matter passes into the solid state under the effects of pressure alone, without going through the intermediate liquid state ordinarily observed at common temperatures.

Hence even with the enormous temperature of the Sun, the whole interior of that immense globe is under such pressure that the matter in confinement behaves as a solid. The nucleus of the Sun is therefore a globe of enormous effective rigidity. At what depth the matter acquires the property of a solid is not certainly known, but it is impossible to believe that the layer which behaves as a gas can have a depth equal to one tenth of the radius; for the pressure at that depth is about 22 million atmospheres. Matter sustaining such pressure must be effectively solid; and if the rigidity is proportional to the pressure, as may be inferred from physical laws which are observationally verified in the case of the Earth, the Sun's matter at a depth of 0.10 of the radius must be about 22 more rigid than nickel steel used in Armor plate.

Accordingly only the outermost layers behave as gaseous matter, while the whole nucleus is rendered effectively solid and highly rigid by pressure. And as convection currents could not be maintained in a mass reduced to the state of a rigid solid, it follows that convection currents can exist only in the outermost layers of the Sun's globe.



The Sun : Rigidity or Pressure in Billions of Atmospheres, 1 div. = Rigidity 1000 times that of Nickel Steel used in Armor Plate.
Density on usual scale, water = 1.
Temperature Scale 1 div. = 3 Million Degrees C.

Heretofore it has been very generally assumed by astronomers that convection currents extend down to the center, and thus produce a steady transfer of heat from the interior outward, so as to maintain the enormous surface luminosity of the Sun's disk.

Some recent views of the convective circulation of the Sun are as follows :

Lord Kelvin : "Gigantic currents throughout the Sun's liquid mass are continually maintained by fluid, slightly cooled by radiation, falling down from the surface, and hot fluid rushing up to take its place". (Address on the Sun's Heat p. 392).

In response to a request of Dr. Vogel, made recently in revising Engelmann's translation of Newcomb's Popular Astronomy, Young has expressed his views very clearly. As given authoritatively in POPULAR ASTRONOMY, April 1904, they are as follows: "From the under surface of this cloud shell (the photosphere), if it really exists, there must necessarily be a continual precipitation into the gaseous nucleus below with a corresponding ascent of vapors from beneath—a vertical circulation of great activity and violence, one effect of which must be a constricting

pressure upon the nucleus much like that of the liquid skin of a bubble upon the enclosed air. With this difference, however, that the photospheric cloud shell is not a continuous sheet, but porous, so to speak, and permeated by vents through which the ascending vapors and gases can force their way into the region above".

In the Article "Sun", Encyclopedia Americana, Newcomb says: "It follows that the heat radiated from the surface must be continually supplied by the rising up of hot material from the interior, which again falls back as it cools off. It is difficult to suppose that even a liquid could rise and fall rapidly enough to keep up the supply of heat constantly radiated. We therefore conclude that the photosphere is really a mass of gas in which, however, solid particles of very refractory substances may be suspended." He says it is probable that the "rice grains" are produced by currents of heated matter from the interior, which are constantly rising to the surface, there to radiate their heat and then fall back again."

In a paper on the "Evolution of Solar Stars" read before the Royal Philosophical Society of Glasgow, Nov. 6, 1901, and published in the proceedings of that learned Society, Professor A. Schuster says:

"It may not be unnecessary to say a few words as to the evidence we possess that the convection currents which play so important a part in the theoretical investigation actually exist in the Sun. The surface radiates an amount of heat into space of which we can form a very fair estimate by measuring the quantity which reaches the Earth. The number so obtained is 1,340 million per square meter of the solar surface, the unit of heat being the amount necessary to raise one gram of water through one degree. We obtain an idea of what that number means if we imagine the Sun to be surrounded by a shell of ice, the heat supplied by radiation could melt in each minute a layer of ice 58 feet thick. Or expressing it with Lord Kelvin in terms of power, we may say that the solar surface does work by radiation equivalent to 131,000 horse-power for each square meter of his surface. The heat thus lost by radiation must be supplied from the inside of the Sun, otherwise the solar surface would cool down in a fraction of a second to a temperature at which it would cease to be luminous. If the heat is carried from the inside to the outside by convection alone, the velocity of the currents of vapor must be very great. Taking the pressure of the vapor near the surface to be one atmosphere, we may

say that all the heat contained in a layer having a thickness of 370 meters is lost by radiation in each second of time, and this number does not depend on the nature of the vapor or on its temperature. A layer of that thickness would have to be replaced by convection in every second if the temperature of the surface is to be maintained. From this I calculate that if the difference in pressure between the descending and ascending currents is one atmosphere, the velocity of the convection currents must be 616 meters per second, or about 1,000 miles per hour. These up and down draughts of vapor must take place with the calculated velocity, unless an appreciable portion of the heat is supplied from the inside in some other way, as for instance by radiation. It is difficult to form an estimate as to how far radiation can help to keep up the temperature of the surface. I have made some calculations on this point which, though they have yielded interesting results, cannot at present be expressed in definite numbers. It is sufficient for the present argument to maintain, that even if radiation takes a prominent part in the determination of distribution of temperature, we cannot escape the conclusion that convective currents must bring about a continuous interchange of matter between the inside and outside of the Sun. This theoretical conclusion is amply confirmed by observation."

Again Schuster adds: "If convection currents could be completely stopped, the heavier gases would sink to lower levels, and the outer layer of a star would be made up of hydrogen and the lighter metallic vapors. It is owing to convection that a mixing takes place, and the stronger the convection the more complete the mixing."

In the writer's paper in *A. N.* 4053 and *A. N.* 4104 it is pointed out that owing to the great internal pressure and rigidity of the Sun's nucleus, convection currents at appreciable depths in the Sun's globe cannot possibly exist; and the heat and light from the Sun's interior must be supplied by direct radiation, as in the passage of the sunlight through the Earth's atmosphere, or by some process of exchange, without bodily movement of streams of solar matter.

"No aim is made in this paper to treat mathematically of the problem of the Sun's surface radiation, but we may remark that the commonly accepted theory of enormous convective currents, one set ascending with highly heated matter and the other descending with the material cooled by radiation, does not seem to be well founded. When the true character of the Sun's radia-

tion is made out, it will be found that the heat and light are supplied in the main not by convective currents, which would necessarily encounter great resistance and constantly antagonize one another by the contrary motions of the neighboring streams of fluid, but by direct radiation—the internal heat being so intense and the overlying medium of gases so thin and transparent to radiation of that intensity that the heat is driven bodily through the Sun's mass with a velocity smaller but not immeasurably smaller than that of light and electricity. In this way the outside surface never cools, nor are great convective currents required to maintain the surface luminosity."

"We may conceive that with the enormously rapid rise of temperature below the photosphere, amounting to from 100000° to 500000 *C* at a depth of 1/100th of the radius or 7000 km. most of the necessary supply of heat is radiated through the flimsy overlying layers of gas, with a velocity but little inferior to that of light. Nor can we conceive of any material of this small density which could resist the terrific heat beneath sufficiently to cause a great fall in the external temperature, even if there were no convective currents whatever. Currents developing at the Sun's surface probably are comparatively shallow and irregular in their character, while the supply of heat from beneath is radiated through the intervening medium with great velocity, thus maintaining the surface in a state of dazzling brilliancy."

"The rapid propagation of heat is not difficult to understand when we remember that by its nature heat is the energy of vibrating molecules of perfect elasticity moving with enormous velocities, in a rare medium, admitting by its abundance vacancies of a vast direct radiation from beneath with the actual velocity of light. The propagation of light in the Earth's atmosphere on a clear day is perhaps nearly analogous to that in the Sun's outer layers just below the photosphere."

"The illumination of the Earth's surface, which enables one to view objects hundreds of kilometers away with but a very slight absorption of their light due to the intervening atmosphere, illustrates the penetrating power of sunlight here upon the Earth, where the intensity is as nothing compared to that in the Sun. Yet the outer layers of the Sun's photosphere are of the same order of density as our atmosphere; and while the carbon and perhaps other particles in the photosphere form a cloud which obstructs the light, no doubt the interior gases are

very transparent. The radiating particles in the photosphere thus derive their heat and light from two sources :

a) Collisions with neighboring particles :

b) Direct radiation from the intensely heated body of the Sun beneath, filling the solid angle of a whole hemisphere."

"The latter source furnishes incomparably the larger part of the radiant energy emitted by the photosphere, and as it is transmitted from the interior with sensibly the velocity of light, there is no opportunity for the cloud-surface to cool, and little or no necessity for convective currents." (*A. N.* 4053).

Since the publication of the above views no criticism of this departure from the old theories has appeared, and the validity of the step rejecting the doctrine of convection currents seems to be generally recognized. In *A. N.* 4131 Schuster indeed has published a criticism of my deduction of the rigidity of the Sun, but it is noticeable that he is careful to offer no defense of the theory of convection currents, about which he was formerly so eloquent. We may therefore confidently hold that convection currents cannot exist except in the shallow outer layers of the Sun's globe, and it is doubtful if they are of much importance even there.

"Great pressure always produces great effective rigidity of the matter, and any motion of matter under such strain would be accompanied by the most enormous molecular friction. It follows therefore that in general when the pressure is very great, enormous resistance would be exerted against currents already existing, and would tend to bring them rapidly to rest; so that the continuation of the motion would presuppose the constant exertion of correspondingly great forces to overcome the friction due to the pressure. As the pressure increases rapidly with the depth in all large masses of moderate density, it seems almost inconceivable that rapidly moving currents could descend to any appreciable depth, and hence all currents observed externally might be expected to be shallow, and to die out rapidly as they descend into the mass."

"These considerations strongly support the views set forth in *A. N.* 4053, that the Sun's supply of light and heat is maintained by direct radiation from beneath rather than by a system of convection currents descending to great depths against the frictional resistance of the surrounding matter. Not only is the resistance to such supposed motion very great, but it is shown that the gases in the outer parts of the Sun's globe are sufficiently rare to admit of a very powerful direct radiation without

bodily motion of the flaming fluid, which is also rendered perfectly transparent by the enormously high temperatures. Moreover it is difficult to conceive of a regular system of double tubes in the continuous body of the Sun, with the hot fluid ascending in one set and the materials cooled by radiation descending in the other. Indeed it seems almost impossible to imagine such a system of currents at work against the resistance inevitably arising from the contrary motion of such neighboring streams. Neither can one see how such a mutually obstructing and antagonistic series of currents could be maintained if once established. Obviously they would all very soon die out, and in view of the proved effective rigidity of the matter, it is impossible to see how they could ever be re-established by any natural process".

"When one reflects that direct radiation does away with this highly complex hypothetical system of movement, while at the same time it affords an adequate supply of energy from below, the conclusion seems irresistible that the general conception of convection currents sinking to great depths in large masses of high average rigidity is a mistaken one; and that the simpler process of direct radiation is the general law of nature. Convection currents might, indeed, exist to some extent in the very shallowest of the photospheric layers of the Sun and the stars, and also in nebulae of small average rigidity; but surely not in the interior of well developed stars having an average effective rigidity thousands of times greater than that of Armor plate.

"The rapid outflow of energy in the case of a typical star would seem to be mainly from the surface layers, though a smaller amount of energy comes up more slowly from greater depths; and no doubt some process of radiation permits the vibrations to be transmitted or exchanged through the intervening medium without bodily motion of matter effectively thousands of times more rigid than nickel steel, though at a temperature of many millions of degrees." (Cf. *A. N.* 4104).

Researches for the interpretation of phenomena noticed at the Sun's surface, to be of any effect, should be guided by the general principles here laid down. Before we can make progress in the treatment of this problem we must base our reduction and discussion of the observed phenomena upon the monatomic theory, or some thing better, and proceed by successive approximations to form a tenable theory of the radiation and fluid movements of the Sun's surface, which will explain observed phenomena in accordance with admissible underlying conditions.

The first need of solar physics to-day is therefore the theoretical study of the radiation of a globe such as we have shown the Sun to be. An effort might be made to trace the observed movements to their appropriate depths. This would give us the true theory of spots, periods, solar drift and kindred phenomena observed on the Sun's disk, and afford the observer a clue to the periodicity and distribution of the eruptions noticed in the photosphere.

Naval Observatory,
Mare Island, California,
May 12, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

For Popular Astronomy.

Part IV. (Continued.)

The Terrestrial Atmosphere. Its Volume, Extent, Density, Pressure, Temperature and the Meteorological Effects caused therein by the Solar Electro-Magnetic Radiations.

A critical examination in the case of hundreds of tornadoes that have been observed at divers times, in different places, has disclosed the fact that the general path, in every case, is toward some easterly point, and in very nearly 400 observed and noted, the direction of the path was toward the northeast in about eighty per cent of that number; ten per cent toward the southeast, three per cent toward the east, four per cent toward E. N. E., one and a half per cent toward N. N. E., one per cent toward E. S. E., and one-half per cent toward S. S. E., the course being, thus, always toward some easterly point, in the great majority of cases toward the northeast. Therefore, when general meteorological conditions are such that a tornado may be expected to pass through, or near, any given place, an observer need look for its approach only from a general westerly

direction,—particularly from points between the southwest and northwest,—the former being by far the more probable point of approach, as indicated in the preceding paragraph. No fear need be felt concerning a tornado-cloud seen eastwardly of the meridian, for such has either passed over the place of observation or, if in process of development, will pass away to the eastward of the observer, and any one who would observe the approach of a tornado from a considerable distance, should scan the southwestern quadrant of the horizon—occasionally glancing at the northwestern quarter—during those seasons of the year, when they are prevalent, and at the hours of the day between which there is the greatest probability of their appearance. Out of every hundred tornadoes observed in the United States (where, in certain regions in which there are, at times, great masses of warm, moist air brought into sudden, and intimate contact with equal masses of cold, dry air through the agency of the radiations from the Sun, with the result of electro-magnetic developments in the terrestrial atmosphere, in a manner to be described, and where these phenomena have been quite fully investigated) the number occurring during certain intervals in the twenty-four hours of the day, is set forth in the following.

TABLE *D*.

Hours	Noon to 2 P. M.	2 P. M. to 6 P. M.	6 P. M. to 8 P. M.	8 P. M. to 10 P. M.	10 P. M. to 10 A. M.	10 A. M. to Noon
Tornadoes	8	60	10	4	12	6

The quantities set forth in this table represent the percentages of distribution during a day and this diurnal period of tornadoes is analogous to those for temperature, wind-velocity and thunder storms, being also quite similar to that for hailstorm frequency, in which the time-interval is about two hours earlier in each case.

The agency of the Sun, by means of its radiant energy, in the causation of all these correlated phenomena, is indicated by an inspection of the quantities in Table *D*, and also by the seasons in which tornadoes are most frequent in the United States, with respect to latitude, the periods being most marked from the vernal equinox, in March, to the autumnal in September, although they have occurred, occasionally, a month, or more, before and after these respective epochs beginning in the lati-

tudes of the Gulf States in the spring and in the northern states in the early summer and then retracing the order, thus with respect to latitude, following almost *pari passu* the motion of the Sun in declination.

The wind-pressures, in pounds per square foot, for velocities at distances up to 600 feet, are beyond those at which all ordinary structures, such as frame buildings, presenting a considerable surface to the wind, and directly exposed to the full force and action thereof, can remain intact, and although walls of heavy masonry may withstand the shock, roofs, and like constructions cannot do so, and we may regard the path of greatest destruction as averaging about 1200 feet in diameter, while beyond the distance of one mile from the axis of the tornado, and up to three miles, the velocities are those of a tropical hurricane; this is also a matter of observation. The mean motion of the air directly within the flue of a tornado is quite directly upward, the velocity of the ascending current as determined by means of equation (1) for a vacuum of fifteen inches is, roundly, 1100 feet per second, so that much of the debris, or portions of structures that have been demolished by the general whirl immediately surrounding the flue, and drawn into the latter, is generally carried upward therein and has been found transported to distances of twenty miles, or so, even when the object thus carried was as large and heavy as a church-spire with its appurtenances.

It is quite probable that the length of the path of any one tornado does not exceed this distance, although published newspaper accounts, in many cases, read as if the length were much greater, but, in most such cases, it is almost a certainty that there are several distinct tornadoes in action at, or about, the same time and in the same section of country, all having had a common origin and traveling in quite close proximity to each other through contiguous regions, as in the case of dust-storms and waterspouts. The tornado that passed over, or through, this city on August 20, 1904 moving N. N. E., was contemporary with a quite similar one that swept across the neighboring city of Minneapolis, Minn., about ten miles distant from St. Paul, both of these tornadoes having had their inception in the same general cyclonic disturbance to the southwest of these cities, and the dimensions etc., of the paths of well-marked destruction were about the same as in the theoretical cases discussed on preceding pages. It may seem quite impossible for any structure, except the most ponderous, to withstand the

tremendous force of the wind-pressure in a tornado, either in the case of the air rotating around the vertical axis thereof, or ascending through the flue, or central part, of the funnel, but it should be noted that unless the exposed surface be very extended whether in the whirl, or in the ascending currents, the onpressing air will flow off laterally and lose much of its theoretical force. Of course, if the base of the funnel were smooth and uniform throughout and the ascending matter packed air-tight therein, this matter would move upward with the velocity of a projectile from a gun.

Moreover, in many cases, the principal parts of any tornado that proceeds in its course by leaps, or bounds, in the manner that I have described on a preceding page, work great material destruction only in spots along the onward path. A most remarkable and instructive phenomenon, not infrequently, observed in connection with a first-class tornado, is the forcible driving of extremely light bodies such as small fragments of wood, and even of *straws*, into the surfaces of wooden houses, standing trees and like objects into which they have been forced to penetrate to considerable depth, although remaining unbroken. To the majority of observers this phenomenon is astounding, and apparently inexplicable, but any one acquainted with certain principles of analytical mechanics will readily see that this strange manifestation of force is due, simply, to the phenomenally enormous velocities with which these light masses, or bodies, are impelled by the wings of the wind. It obviously requires, in each case, a definite quantity of kinetic energy, in these masses, to cause their penetration into other bodies, the quantity of this energy being, as is quite well-known, directly proportional to the mass (M) and the square of the velocity (V), the kinetic energy (E) being expressed by the equations :—

$$E = \frac{MV^2}{2} = \frac{WV^2}{2g};$$

so that any decrease in mass (M), or weight (W), will be more than compensated by increase of velocity (V), in the same ratio that the weight is diminished, the increase of kinetic energy being *double* for twice the velocity although the weight in motion is cut to *one-half* its original value. In the equations set forth just above, the quantity designated by g is the acceleration due to the force of terrestrial gravity, its normal value being, very nearly, 32.2 feet per second, and the mathematical relation between the kinetic energy (E) of any projectile of weight (W), moving with a velocity (V), in feet per second, and

the penetration (t) into a substance of any kind—such as armor-plate—is expressed by the following equations :—

$$\frac{E}{C} = \frac{W V^2}{2 g C} = k^2 t^2 ; \qquad (a)$$

in which C represents the circumference of the projectile, in inches, and t the number of inches perforated, the weight (W) being expressed in tons, and the energy (E) consequently in "foot-tons". From equations (a) we have, for the determination of the velocity (V) when the weight (W), circumference (C), and the penetration (t), of a projectile are known, and of said penetration when the other quantities are evaluated, the following equations :—

$$V = \frac{V\,\overline{2gC}\; k t}{W^{1/2}} = \frac{8.02\, C^{1/2}\, k t}{W^{1/2}} ; \qquad (b)$$

$$t = \frac{W^{1/2}\, V}{8.02\, C^{1/2}\, k} . \qquad (c)$$

The value of k as determined experimentally, is, for wrought-iron plates, 0.819, and for pine-wood, 0.158, it being, according to my determination, proportional to the *tensile strengths* of these materials (which are 62,000 and 12,000 pounds per square inch respectively,) the case being somewhat analogous to that of the breaking-stress in a beam, of unit length and breadth, in which the strength is proportional to the square of the depth, or thickness, (t), and, in proof of the accuracy and sufficiency of my equation, in this connection, I adduce the following practical applications derived from the experiments of Gunnery.

It is clearly indicated in the last equation that, for any given velocity, the power of penetration of a projectile of any kind is inversely proportional to the square root of the circumference of the latter, a fact that is taken advantage of in Gunnery by reducing the diameter, and making up the required weight by increasing the length, of the projectile which, therefore is given the well-known conical shape. On the same principle, even a light straw, by reason of its form and the enormous velocity with which it is impelled by the wind in a tornado, is occasionally found sticking firmly in surfaces of harder material, to the astonishment of observers of this phenomenon. Verily, in this case, "straws show how the wind blows" and particularly its enormous velocity.

A projectile having a weight (W) of 0.852 of a ton, a circumference (C) of 50¼ inches, fired from an eighty-ton gun, with a muzzle velocity of a little more than 1625 feet per second, after

passing over a range of 3000 feet, made impact with armor-plate for which the coefficient (k) was 0.819, the velocity (V) of impact being 1526 feet per second. Therefore, all the quantities necessary for the determination of the thickness (t) of armor-plate just perforated by the projectile, are known, and employing them in equation (c), as indicated, I have found the value of (t) to be 30.24 inches, while the thickness actually perforated was 30.2 inches; so that my equations (b) and (c) which have been rigorously derived, while most of those that have been used are only empirical, may be regarded as true and accurate.

But my particular purpose, in going into this matter at such length, is to determine the velocity of the wind in a tornado by means of the depth to which even light fragments of matter carried by the air-currents rotating with otherwise immeasurable velocity around the axis of the funnel, have been forced to penetrate material surfaces stationary in the path of the storm, because the motion and energy of such fragments are analogous to those in the case of the projectile aforesaid. Some time ago, I examined a thin fragment, or pencil, of wood, two inches long, with a circumference (C) of 0.7-inch, and a weight (W) of only seven grains avoirdupois, or the two-millionth part of a ton, which had been forced by the tornado on August 20, 1904, (the passage whereof through this city, I have described, in detail, on preceding pages,) through the clap-boarding and into the inner boards of a house about 250 feet from the center, or axis, of the tornado, the total thickness (t) penetrated having been about 0.7-inch. Using these values and that of k (which is 0.158 for pine-wood as aforesaid) as indicated in equation (b), the velocity (V) with which this small, light fragment of wood was projected by the tornado-wind, I have found was 1050 feet per second, or 716 miles per hour, while the velocity interpolated from the theoretical values in my Table C on a preceding page, for the distance of 250 feet from the axis of the whirl, is practically the same—a fact that proves the concordance between the deductions from my theory, and the facts of observation. Of course, a wind blowing with that velocity could not act against any ordinary structure for more than a comparatively few seconds without leveling it, or inflicting more damage than that observed; but these central portions of a tornado, where the wind-velocities are enormous, pass onward at an average rate of thirty miles per hour, and not infrequently at double this rate, or, roundly, at as much as 100 feet per second, so

that a central portion, of about 600 feet in diameter, in which the velocity of the wind is 600 miles per hour, or more, would pass by a given point of the path in only six seconds, the time near the extremity of the radius of 300 feet being, much less, or not more than one or two seconds, and the action would be so evanescent that it would seem like a sudden stroke from some mighty, unseen weapon, particularly if occurring in the darkness of the night as it did in this case. I questioned many persons who either resided, or happened to be, within 600 feet, or there about, from the central line, as to their impressions of the occurrence, and none seemed to recognize the nature of the phenomenon,—all asking me what it was, and saying that everything was over in less than a minute and all appeared to be dazed by the phenomenon. My personal impression of the first blow that struck the large dwelling in which I resided at that time, was that it was an earthquake-shock rather than the effect of a tornado, or a hurricane. All the observed facts in connection with this, and other, tornadoes corroborate my theoretical conclusions concerning the nature and mode of operation of these phenomena, and lead to a consideration of that much larger atmospheric vortex (in the southeast quadrant of which they are generally formed), which is primarily due to the Sun's radiant energy, and is, properly, and scientifically, called a "cyclone", or a "low", in the language of meteorology.

The destruction wrought by a tornado is not caused by the excessively high wind only, for, in some cases, when the center of this aerial vortex passes directly, and quickly, over a closed building, the atmospheric pressure on the outside and in, or near, the flue of the funnel, is reduced so greatly, and suddenly, below the nearly normal pressure of the air within the building, that windows, roof and sometimes the walls are thrown onward with great violence, this action being due to the almost explosive expansion of the air confined within the structure the complete shattering whereof indicates, clearly, the enormous and sudden reduction of the atmospheric pressure outside, as the center of the tornado passes over the building, the air within which is thus at a relatively high pressure, and being unable to escape gradually, the result must be akin to an explosion.

The circular section of what I have termed the "flue" of the funnel of a tornado, up through which the rarefied and electrified air ascends at the rate of, roundly, 1100 feet per second (according to my determination set forth on a preceding page),

by reason of the excess of the external atmospheric pressure over that within the flue in which the pressure is about 7⅓ pounds per square inch, or only one-half the normal pressure of of the atmosphere, has a radius of twenty-five feet and, therefore, a circumference of 157 feet, but these are only *mean* values, and this central portion, or flue, instead of being cyclindrical may be —and probably is—more, or less, conical, or even of some irregular form, but this fact does not materially affect the conditions of the problem in this connection.

As I have demonstrated, and set forth in Tables *A* and *C*, in the preceding number of POPULAR ASTRONOMY, just at the outer end of the radius of the flue, or twenty-five feet from the center of the tornado, the air is revolving around the more, or less, vertical axis of the latter, with the maximum, horizontal velocity of 3400 feet per second, and since the circumference of a circle having this radius is 157 feet, the number of revolutions per second, is obviously $\frac{3400}{157} = 21.7$, and this is to be taken as the unit number of revolutions at unit-radius of twenty-five feet from the center of the tornado, from which the number (n) at any other radius (ρ), or distance from that center is determinable through the equation :–

$$n = \frac{21.7}{\left(\frac{\rho}{25}\right)^{1.5}}.$$

For any radius (ρ) the circumference, obviously, *increases* directly, with this radius, while, as I have demonstrated, the wind-velocity *decreases* as the square root of the radius, the combined effect being, therefore, inversely proprtional to $\rho^{1.5}$, as indicated by the denominator in the right-hand member of this equation for the number of revolutions per second, the reciprocal whereof $\left(\frac{1}{n}\right)$ expresses the unit-time of one revolution, which is, therefore, in this case, only $\frac{21.7}{1}$ of a second.

It may be more convenient, and preferable, to use the diameter (δ) of the tornado, instead of the semi-diameter, or radius (ρ), thereof, in which case there results the equation :—

$$n = \frac{21.7}{\left(\frac{\delta}{50}\right)^{1.5}} = \frac{7672}{\delta^{1.5}} ;$$

and for the time (t) of a single revolution,

$$t = \frac{\delta^{1.5}}{7672}.$$

Although, as I have pointed out, the influence of a tornado, in causing high wind, may extend, in some degree, for twenty miles, even more, on each side of the comparatively narrow central path, the consequent, or induced, wind-velocities beyond a distance of one mile, at which the velocity is 160 miles per hour, and up to four miles, at which it is eighty miles per hour, as indicated in Table *C*, are those of a tropical hurricane induced by a true *cyclone*, or extensive area of low barometric pressure, the velocity decreasing gradually to thirty-five miles per hour,—which is that of a moderately high wind—at the distance of twenty miles from the center of the tornado, and to lower velocities indefinitely beyond, but, as stated, the maximum radius of the tornado proper may be regarded as one mile, and the diameter, therefore, as two miles, or, roundly, 11000 feet where the limiting velocity in the outer rim of the vortex is 160 miles per hour. This maximum diameter is almost exactly that derived from observations of several hundred tornadoes, so that if we take 11000 as the value of δ for use in the equations last set forth, the number of revolutions at this outer limit of the tornado, is found to be only 0.0066, and the period of a complete revolution, 150 seconds, or 2½ minutes, and the time of transit of any point in the outer whirl, from the left-hand edge of the funnel to the right-hand one, or of a semi-revolution, is therefore, 1¼ minutes as against only the $\frac{1}{21.7}$ part of a second, and 21.7 revolutions per second, at the minimum distance, or radius (ρ), of twenty-five feet from the center of the tornado, at which distance the wind-velocity is at the maximum of 2320 miles per hour. The average diameter of a very large number of tornadoes observed has been found to be, roundly, 1100 feet and this used in the above equations, as the value of (δ) gives, as the number (n) of revolutions per second, 0.2 and as the time of a complete turn, five seconds; in the same manner, the values for any other point can be found.

As above demonstrated, in the case of the maximum diameter (11000), the time of one-half a revolution is 1¼ minutes, and if a portion of the tornado-cloud remain well-defined, or if a definite object therein be discernible moving around with the velocity of the air current, during a semi-revolution, it would be found to pass, or transit, from the left-hand side, or edge, of the funnel, to the right-hand edge thereof, in 1¼ minutes, if my

theoretical determinations in this connection be correct. It, therefore, becomes possible to determine the wind-velocity in the outer, visible, portion of the funnel of any tornado, in a very simple, but perfectly rigorous and accurate, manner, all that is necessary for an observer to determine being the linear diameter of the funnel, by means of its angular diameter and distance from the observer, and the time required for the transit of a definite object, or a portion of the tornado-cloud itself, from the left-hand edge of the funnel, to the right-hand edge thereof. This would be an easy matter for any intelligent observer (possessing a knowledge of only the elementary principles of plane trigonometry) either with, or without, instruments for the measurement of angles, and located at a safe and convenient distance on either side of the path of the tornado, preferably in a level region such as a western plain, or prairie, where they happen to be most be frequent, and from the external velocity so found, the internal velocity at any distance from the center of the funnel can be deduced by means of the mathematical relations that I have demonstrated on preceding pages; by this means my theory, in this connection, can be put to the test of observation, and I hope that this will be done by some observer in the near future, when opportunity presents. This proposition is not, at all, a *chimerical* one as many persons can quite accurately estimate, off-hand, angular distances and time-intervals, while the distance of the *center* of the funnel of the tornado from the point of observation, can be ascertained afterward from the location of the central line of the path which is, in most cases, well-defined, the whole process involving only a knowledge of plane trigonometry.

Saint Paul, Minnesota.

To be continued.

A SIMPLE METHOD DEVISED BY F. C. PENROSE FOR FINDING THE ORBIT OF A HEAVENLY BODY BY A GRAPHICAL PROCESS. V

ERIC DOOLITTLE

For Popular Astronomy.

18.—We will now subject the graphical method to the most severe test possible by applying it to the orbit of a comet which has been observed but three times since its discovery. The first

telegram announcing the appearance of a new comet always states its position among the stars and the direction in which it is seen to be moving. From this the body is frequently found and measured on the following night, but it is not until three nights' measures have been secured that its path can be determined.

It is rather unusual for all three measures to be secured on successive nights, that is, within forty-eight hours of its discovery, and when this is the case, the arc passed over by the body is so short that the elements of its path are necessarily uncertain. All that is expected of this first determination is that it shall give some indication of the size and position of the true orbit, and shall also enable us to predict the place of the body in the sky for an interval of two or three weeks with enough accuracy so that it may be found without difficulty.

DETERMINATION OF THE ORBIT OF COMET 1907 *e*, (MELLISH).

To illustrate the graphical determination of a preliminary orbit and to show how the so-called *Search Ephemeris* is determined, we select from the *Bulletin of the Lick Observatory*, No. 121, the three following observations, which were the first three measures made on the above comet after its discovery.

1907 G. M. T.	App. α	App. δ
Oct. 15.6784	$8^h\ 26^m\ 13.0^s$	$-8°\ 45'\ 16''$
16.9782	8 22 25.1	−8 12 6
17.9892	8 19 13.1	−7 44 15

Changing the times to Berlin mean time, and taking the positions of the Earth from the *Berliner Jahrbuch* for 1907, page 17, as in previous cases, we obtain,

B. M. T.	L	log R	R
Oct. 15.7156	21° 39′ 5″	9.99859	0.9968
17.0154	22 56 27	9.99842	0.9964
18.0264	23 56 40	9.99830	0.9961

The corrections which must be subtracted from the above right ascensions and declinations in order to obtain the values which these quantities would have had if the measures could have made from the positions which the equator and vernal equinox occupied at the beginning of the year were not printed with the observations; if it is thought necessary to apply these, they must be computed by the formulas given in the Berliner Jahrbuch, page 312. This was done in this case, the resulting right ascensions and declinations were changed into degrees, minutes, and seconds, and finally, employing the value 23° 27′ 5″

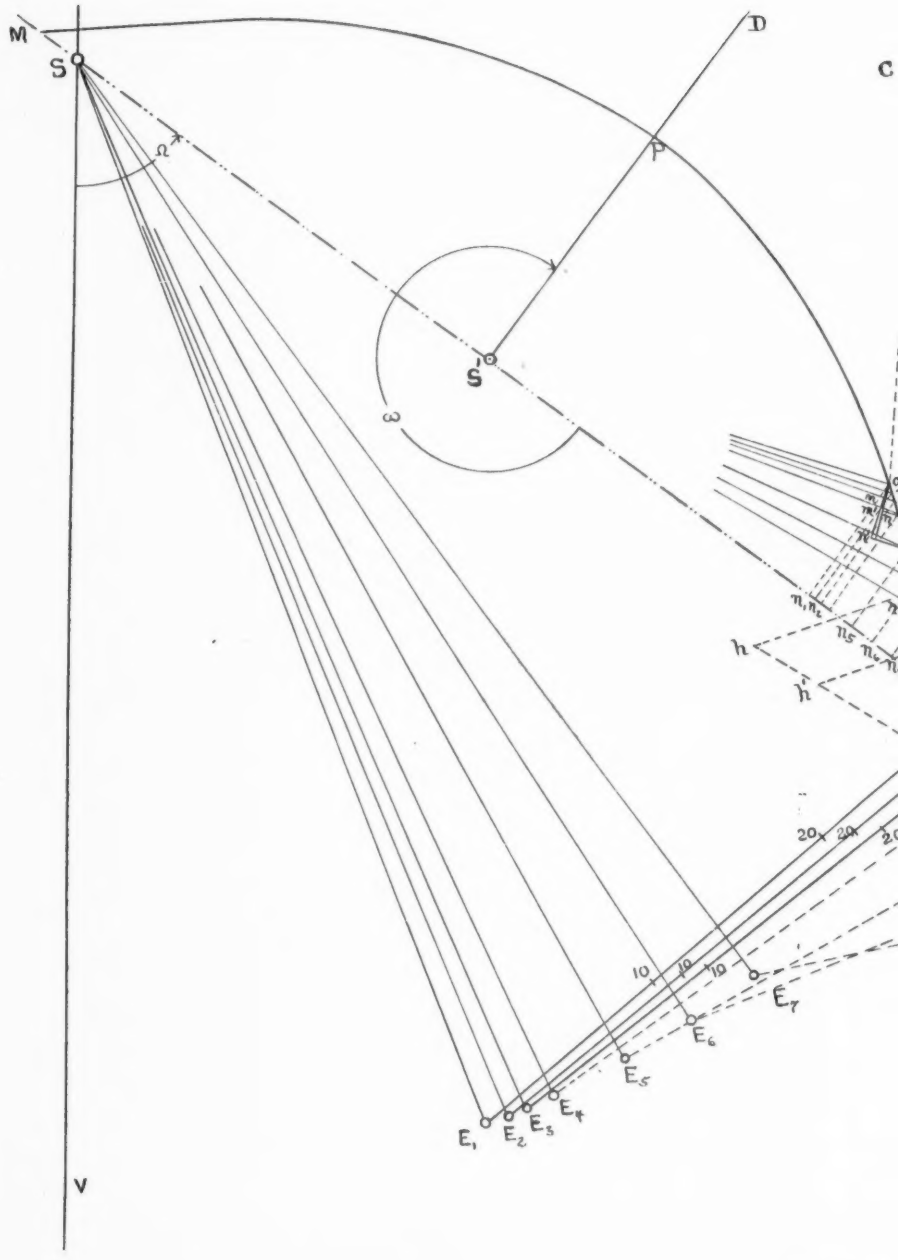


FIGURE 14

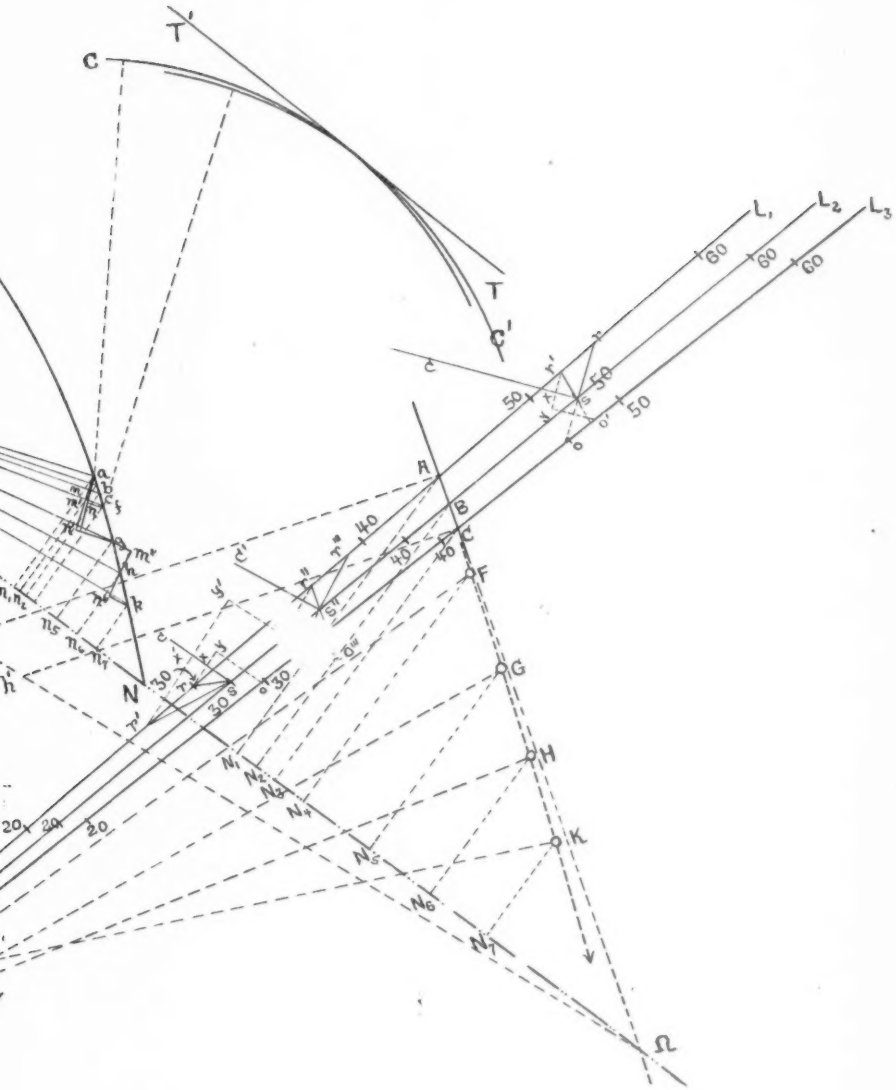

T'
C
T
C'
L1
L2
L3
60
60
60
50
50
50
A
B
C
F
G
H
K
Ω
N
N1
N2
N3
N4
N5
N6
N7
40
40
40
30
30
30
20
20
20

FIGURE 14

for the obliquity of the ecliptic from page 1, the corresponding latitudes and longitudes were determined as has already been fully described. The results are as follows:

No.	λ	β
1	131° 23′ 29″	−27° 6′ 19″
2	130 12 39	−26 49 7
3	129 13 21	−26 34 17

Selecting a point S to represent the Sun and drawing the line SV to indicate the direction of the vernal equinox, we lay off the positions of the Earth and draw the corresponding longitude lines by employing the tangents or cotangents of the several longitudes as described in (14). We find,

No.	tan L	cot λ	cot β
1	0.3970	0.8809	1.9538
2	0.4232	0.8454	1.9781
3	0.4440	0.8162	1.9994

We next graduate the longitude lines by laying off $E_1\,10 = 19.54$, $E_1\,20 = 39.08$, etc., $E_2\,10 = 19.78$, $E_2\,20 = 39.56$, etc., $E_3\,10 = 19.99$, $E_3\,20 = 39.98$, etc., and we are then ready to search for the true position of the projected arc. We have,

$$t_2 - t_1 = 1.2998$$
$$t_3 - t_2 = 1.0110,$$

and hence,

$$a_1 \div a_2 = (t_2 - t_1) \div (t_3 - t_2) = 1.2857.$$

As the elapsed time is only two days, the projected arc must be sensibly a straight line, or at most have only a very slight curvature, concave toward the Sun, for the arc of any parabola whose focus is at S included between the first and last sight lines will necessarily appear to be nearly a straight line, and its projection will also have almost no appreciable curvature. As a first trial we draw rs through the latitude number 30 for the first part of the arc; then joining scS, drawing rxy perpendicular to sc, making $xy = rx \div 1.286$, and finally drawing yo parallel to sc, we obtain the second extremity of our projected arc at o. But since rso is convex toward S, this cannot be the projection.

If we incline rs still further toward the left so that it occupies the position $r's$, and draw similarly $r'x'y'$ perpendicular to sc, making $x'y = r'x' \div 1.286$, the last extremity, located at o' by drawing $y'o'$ parallel to sc, will be found to render the arc more strongly convex toward the Sun than before. We therefore conclude that if the projected arc lies in this neighborhood

it must be inclined in the other direction, that is, in a direction from y to s instead of from r to s.

A further test of any arc, for example $r'so'$, may be made by employing the latitude numbers. Since the arc of the true orbit in space, ro, Figure 15, is sensibly a straight line, we have

$$\sin Krs = \frac{sK}{rs} = \sin osH = \frac{oH}{os}.$$

Hence,

$$\frac{sK}{rs} = \frac{oH}{os}, \quad \text{or} \quad \frac{sK}{oH} = \frac{rs}{os}.$$

But $sK = ss - rr'$ = (latitude number of s) — (latitude number of r'); oH = (latitude number of o') — (latitude number of s), and $rs \div os$ is equal to the ratio of the corresponding areas and

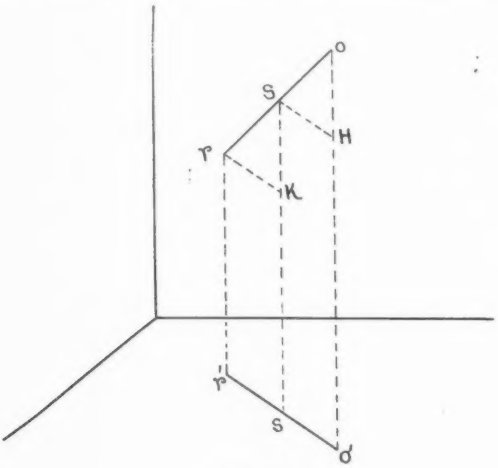


FIGURE 15.

hence = 1.286. Representing the difference of the first two latitude numbers by b_1 and that of the second two by b_2, we must therefore have,

$$b_1 \div b_2 = 1.286.$$

We find by measurement, latitude number of $r' = 27.24$, of $s = 30.00$, and of $o' = 31.87$; hence $b_1 = 30.00 - 27.24 = 2.76$, $b_2 = 31.87 - 30.00 = 1.87$, and $b_1 \div b_2 = 1.48$, which does not satisfy the above equation. To find where the condition arising from the latitude numbers will locate o' after r and s have been chosen, we compute b_2 from the equation $b_2 = 2.76 \div 1.286 = 2.14$, and hence o' must be at the point whose latitude num-

ber is 32.14. This locates the third point at o''', a position which does not satisfy the law of areas.

If we move the projected orbit toward the right, still keeping the arc inclined in the direction sr or sr', we find that the orbit, becomes more convex toward the Sun and that the disagreement with the equation just derived from the latitude numbers increases. If we move it toward the left, the latter condition is not satisfied until the arc coincides with the Earth's orbit E_1E_3; for these points the second condition is necessarily satisfied since $b_1 = b_2 = 0$, and the first condition is, of course, satisfied by this location also. We therefore conclude that the point r or r' must lie to the right of sc, and that the motion of the comet is retrograde.

To avoid confusing the figure, we draw the first trial orbit in this new direction at the point whose latitude number is 35. The position $r'''s''$ renders the orbit convex toward S as before. but this convexity diminishes as r''' is moved toward the left. The position $r''s''$, for example, locates the extremity at o'', rendering the arc slightly concave toward S. This curvature, though slight, is greater than we should expect and a careful measurement of the latitude numbers shows that the second condition is not satisfied, for we have, latitude number of $r''=36.82$, of $s''=35.00$, and of $o''=33.60$, whence $b_1 \div b_2 = 1.82 \div 1.40 = 1.30$, a number which is slightly too great. Were it not for the too great curvature, however, we would suspect that the position $r''s''$ was very near the true one. (This curvature can readily be diminished by moving r'' toward r''', but this causes the latitude numbers to disagree).

If, keeping $r''s''$ parallel to itself, we displace this arc toward the right, its curvature will lessen and the second condition become more nearly satisfied; if we displace it too far, however, for example to the point whose latitude number is 50, then we find that a great inclination, rs, renders the arc convex toward S while a small one $r's$, does not satisfy the second condition. In short, we find that there is only one small region lying slightly to the right of the points whose latitude numbers are 40 for which both conditions are satisfied. The direction of the arc is also fixed with but very little uncertainty; a very few trials similar to those which have just been described lead to the line ABC as the best position of the projected orbit. For this position we find, latitude number of $A = 45.08$, of $B = 42.73$, and of $C = 40.90$; hence $b_1 = 2.35$, $b_2 = 1.83$, and $b_1 \div b_2 = 1.285$. The law of areas is also exactly satisfied.

Thus, even in this difficult case, we see that the graphical method will locate the projected arc with considerable accuracy. In the original drawing the distance SE_1 corresponded to ten inches and on this scale the arc AC could hardly have been displaced one quarter of an inch in either direction without sensibly rendering the conditions employed in its determination unsatisfied.

To find the elements of the true orbit, we now draw Ah and Ch' perpendicular to AC and equal to 45.08 and 40.90, respectively, join hh', and produce this line to meet AC produced in Ω. The line $S\Omega$ is then the line of nodes and we find by measurement $VS\Omega = \Omega = 54° 54'$. Since tan i = latitude number of $A \div AN_1$ = latitude number of $B \div BN_2$, etc., we also find,

	Lat. No.	AN_1 etc.	tan i	i
A	45.08	30.00	1.503	123° 37′
B	42.73	28.43	1.498	123 44
C	40.90	27.20	1.509	123 32,

whence, from the mean of the three values, $i = 123° 38'$.

To draw the true orbit, we choose a point S' to represent the Sun and employing a scale one-third as great as that used before lay off $S'n_1 = \frac{1}{3}SN_1$, $S'n_2 = \frac{1}{3}SN_2$, etc., and $n_1a = \frac{1}{3}N_1A$ sec i, $n_2b = \frac{1}{3}N_2B$ sec i, etc. We find, sec $i = 1.201$, N_1A sec $i = 36.00$, N_2B sec $i = 34.11$, and N_3C sec $i = 32.64$. With a center a and a radius aS', we describe the arc C, and with a center c and a radius cS', we describe the arc C'; we then draw TT' tangent to these arcs and $S'D$ perpendicular to TT', marking the perihelion P, midway between S' and TT'. Finally, having the focus S' and the directrix TT', we draw the parabola MN as in previous cases.

We find by measurement, $S'P = q = 0.739$, $NS'P = \omega = 271° 2'$, and finally, by comparing the area $PS'a$ with $aS'c$, T = Sept. 3.740. The entire system of elements compare with those derived by computation from the same observations as follows.

	Graphical Method	Computation
T	Sept. 3.740	Sept. 16.1274
ω	271° 2′	296° 45′.9
Ω	54 54	53 36 .3
i	123 38	120 11 .9
q	0.739	0.9874

19.—*Determination of an Ephemeris.*—We will now apply the method of (13) to find the position of this comet in the sky at midnight of every fourth day from the time of the last observation until the end of the month. The several dates will be,

$t_4 =$ Oct. 19.5
$t_5 =$ 23.5
$t_6 =$ 27.5
$t_7 =$ 31.5

Since $(t_4 - t_3) \div (t_3 - t_1) = 1.474 \div 2.311 = 0.638$, we draw amn perpendicular to cS', making $mn = 0.638 \times am$, and nf parallel to cS', and thus obtain the point f for the position of the comet in the true orbit on the fourth date.

Similarly, since $(t_5 - t_4) \div (t_4 - t_1) = 4.00 \div 3.784 = 1.057$, we draw $am'n'$ perpendicular to fS' and $n'g$ parallel to fS', making $m'n' = 1.057 \times am'$ and obtain the point g. Similarly the point h is located, after which we draw $m''n''$ perpendicular to hS' and gm parallel to hS', lay off $hn'' = hm''$, draw $n''k$ parallel to hS', and so obtain the last position at k.

We next let fall the perpendiculars fn_4, gn_5, etc., measure $S'n_4$, $S'n_5$, etc., lay off $SN_4 = 3xS'n_4$, $SN_5 = 3xS'n_5$, etc., and at the points N_4, N_5, etc., erect perpendiculars laying off on them the distances $N_4F = 3xn_4f \cos i$, $N_5G = 3xn_5g \cos i$, etc. The points so obtained are the successive positions on the projected orbit.

From the Berliner Jahrbuch, page 17, we now copy the values of L and R from which we obtain as usual the positions of the Earth at E_4, E_5, etc.

No.	Date	L	log R	R	tan L
4	Oct. 19.5	25° 24′ 29″	9.99811	0.9957	0.4750
5	23.5	29 23 14	9.99763	0.9945	0.5631
6	27.5	33 22 32	9.99717	0.9935	0.6588
7	31.5	37 21 25	9.99672	0.9925	0.7633

Joining E_4F, E_5G, etc., and measuring the angles which these lines form with the direction SV, we obtain the following values of the longitudes of the comet :

No.	λ
4	127° 24′
5	121 45
6	114 19
7	104 33

The corresponding latitudes are obtained from the equations derived in (13) :

$$\tan \beta_4 = \frac{FN_4}{E_4F} \tan i, \quad \tan \beta_5 = \frac{GN_5}{E_5G} \tan i, \text{ etc.}$$

We find, $\tan i = 1.503$;

No.	FN_4 etc.	E_4F etc.	$(FN_4 \div E_4F)$ etc.	β
4	25.20	77.60	0.3247	−26° 1′
5	20.71	68.56	0.3020	−24 25
6	16.06	60.56	0.2626	−21 37
7	11.76	53.80	0.2185	−18 11

The values of β are evidently negative since the comet has not yet passed the ascending node.

It now only remains to derive the right ascensions and declinations which correspond to the above longitudes and latitudes. The most convenient method of doing this is exactly similar to that of the inverse problem described in (14). We first compute two auxiliary quantities m and M from the equations,

$$m \sin M = \sin \beta$$
$$m \cos M = \sin \lambda \cos \beta,$$

and then find α and δ from the equations,

$$\tan \alpha = \frac{m \cos (M + \epsilon)}{\cos \lambda \cos \beta},$$

$$\sin \delta = m \sin (M + \epsilon).$$

The entire computation for the first date of the ephemeris is as follows :

$\sin \lambda$	9.90005 p	$\sin (u + \epsilon)$	9.14891 n
$\cos \beta$	9.95366 p	$\log m$	9.92317 p
$\cos \lambda$	9.78346 n	$\cos (u + \epsilon)$	9.99565 p
$\sin \beta = m \sin M$	9.64184 n	$\sin \delta$	9.07208 n
$m \cos u$	9.85371 p	$\cos \lambda \cos \beta$	9.73712 n
$\cos u$	9.93054 p	$\tan \alpha$	0.18170 n
$\tan u$	9.78813 n	δ	$-6^\circ\ 47'$
u	$-31^\circ\ 33'$	α	$123^\circ\ 21'$
$u + \epsilon$	$-8^\circ\ 6'$	α	$8^h\ 13^m\ 24^s$

The four resulting positions are given below, and for comparison with these the values are written which were derived by computation. It will be seen that the positions of the comet obtained by the graphical method are in this case quite accurate enough to enable the body to be followed for ten days or two weeks after its discovery.

EPHEMERIS.

Berlin M. T.	α	δ
1907 Oct. 19.5	$8^h\ 13^m\ 24^s$	$-6^\circ\ 47'$
23.5	7 54 52	-4 11
27.5	7 30 0	-0 3
31.5	6 55 24	$+4$ 34

EPHEMERIS FROM COMPUTATION.*

B. M. T.	α	δ
1907 Oct. 19.5	$8^h\ 13^m\ 49^s$	$-6^\circ\ 56'$
23.5	7 56 39	-4 29
27.5	7 33 31	-1 7
31.5	7 0 48	$+3$ 33

The End.

University of Pennsylvania.

* Lick Observatory Bulletin No. 121.

GRAVITATION.* II

CHARLES MORRIS.

It may be desirable, in concluding this paper, to state briefly what results have been reached in precdeing gravitation hypotheses. It is interesting to note that all of these are based on some action of an ether supposed to pervade space, and in nearly all cases they confine themselves to the energy effect of this substance on the spheres considered as wholes. Two only of them are based upon a special ether, separate from the ordinarily accepted ether. Sir William Thomson (Lord Kelvin) suggests that the phenomena of gravitation might be explained by the action of an incompressible fluid filling all space, created constantly in each particle and flowing off into infinity, or created at infinite distances and flowing in all directions in upon each particle. This idea of incessant new creation is too remote from scientific conceptions to be for a moment considered. The other hypothesis is that of the ultramundane corpuscles of Le Sage, interesting from the fact that it alone among gravitation hypotheses gained wide acceptance, and finds adherents.

The Le Sage corpuscles consist in a vast number of minute particles moving rapidly in all directions, impinging upon every mass of matter and condensing it by the force of their impact. Where two spheres are sufficiently near each other, each "shadows" the other, that is, screens the other from a certain number of the corpuscles. There are thus fewer blows on their opposed faces than on their more distant faces, and this excess of impacts on their distant sides acts to force them towards each other.

This hypothesis has the advantage of dealing with molecules and atoms as well as with spheres, its swift-flying corpuscles being supposed to pentrate the spheres to their inmost recesses. Its simplicity and conceivable adequacy, as compared with other hypotheses has rendered it attractive, even to many scientists. Yet it has been rejected by the great body of physicists for several reasons. Its requirement of a second ether, pervading a universe supposed to be already fully occupied by an ether of different character, is exceedingly improbable. And Clerk-Maxwell has demonstrated that the energy exerted by these corpuscles would far surpass that needed for gravitative purposes and, converted into heat, would be sufficient to raise

* *The Journal* of the Franklin Institute, March, 1909.

the spheres to a melting temperature in a brief period. As regards the problem of the instantaneous transmission of gravitative force, it does not deal with it at all.

These points are dwelt upon here from the fact that the present hypothesis, while radically different from that of Le Sage, is like it in dealing with an ether that penetrates the spheres and acts upon every molecule of matter, and also formulates a condition somewhat like that of the "shadowing" of neighboring spheres by each other. It, however, deals with these subjects from a different point of view. Instead of presenting a flying corpuscle, striking the molecule with its full energy, and likely to yield far more force than is needed for gravitative purposes, it replaces impact by vibratory pressure in which only the energy needed is employed, all excess of energy being taken up by the molecules as vibration and passed onward to the ether beyond. Thus it does away with the necessity of a special ether, adapted to this function alone, and disposes of the difficulty of a surplus energy, while the "shadowing" action is replaced by a more effective mechanism. It further is in accordance with the phenomenon of the instantaneous transmission over great distances of the gravitative effect. This is a crucial element in the problem. Instead of dealing with a simple action between Sun and planet, it seeks to make this principle universal by showing that each sphere or mass of matter is surrounded by an atmosphere of weakened ether energy, decreasing in effect outwardly in strict accordance with the Newtonian law of gravitation. In this atmosphere all external spheres swim, so that their gravitation toward the acting body at each instant must exactly accord with their distance and vary in accordance with every change in distance, the time element being thus removed. There are other conditions, of a less stringent nature than this, demanded of all attempted explanations of gravitation, but these it is not necessary to name here, as none of them are violated by the present hypothesis.

(Concluded.)

[SUPPLEMENTARY NOTE.—Since reading the proofs of the above my attention has been called to an article by O. Keeler, in Comptes Rendus, vol. 147, pages 853-856 (Nov. 9, 1908), on the Reaction of the Ether on Matter as a Cause of Universal Attraction in weich the author shows that if the primary atoms (atomules) emit radiations, which like radiation, are capable of exerting pressure, then matter composed of atoms will be subjected to an attraction similar to that required by Newton's law of gravitation. In relation to this suggestion I would say that the conclusion reached is an obvious one, in view of the recent demonstration that the rays of light exert some degree of compressive force upon matter.]

PLANET NOTES FOR JULY AND AUGUST, 1909.

Mercury will be at greatest elongation, west from the Sun 21° 12′, on July 7, and will be visible as morning star for a few mornings before and after that time. The planet at that time will be about 20° north declination and so must be looked for pretty well around toward the northeastern horizon. On

THE CONSTELLATIONS AT 9:00 P. M., AUGUST 1, 1909.

Aug. 4, Mercury will be at superior conjunction, and it will be invisible for the remainder of the month.

Venus is evening star slowly moving out from the Sun's glare and slowly increasing in brightness. She may be seen in the west soon after sunset. Her course during these months will be southeastward through Cancer and Leo.

On Aug. 11, she will pass quite close to Jupiter. The two planets will appear as twins for several days before and after this time. Their closest approach will be on Aug. 11 at 19^h, Greenwich mean time, when Venus will be 12′, or less than half the Moon's diameter north of Jupiter.

Mars may be observed in the morning being near the meridian at five o'clock on July 1 and at two o'clock on Aug. 31. During these two months the apparent diameter of Mars will increase from 15″ to 24″. The phase being nearly full the markings of Mars may be studied under fairly satisfactory conditions.

Jupiter may be seen in the west during the early evening, but is getting too near the Sun for satisfactory study. The conjunction of Jupiter has already been mentioned. Mercury will be in conjunction with Jupiter, the former being 40′ to the south of the latter on Aug. 15 at noon Greenwich mean time.

Saturn will be at quadrature, 90° west from the Sun on July 15, and so may be studied in the morning hours. The planet will be almost stationary in Pisces during these two months, the motion being eastward until Aug. 5 and after that retrograde.

Uranus will be at opposition on July 11 and so will be in best position for study during these months. The course of the planet is short in Sagittarius, its movement being slow, westward.

Neptune will be in conjunction with the Sun on July 9, so that it will not be visible during these months.

Occultations visible at Washington.

Date 1909	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N. °	EMERSION. Washington M.T. h m	Angle f'm N °	Duration. h m
July 1	191 B. Ophiuchi	6.3	5 38	136	6 33	262	0 55
1	*b* Ophiuchi	4.4	6 04	100	7 08	299	1 04
2	λ Sagittarii	2.9	7 25	44	8 00	340	0 35
5	37 Capricorni	5.7	9 34	65	10 36	273	1 02
5	145 B. Capricorni	6.1	14 04	86	15 18	224	1 14
10	64 Ceti	5.8	13 59	55	15 00	245	1 01
10	ξ^1 Ceti	4.5	14 55	47	16 00	250	1 05
12	163 B. Tauri	5.8	14 52	125	15 22	187	0 30
27	84 B. Scorpii	6.3	9 58	114	11 17	276	1 19
27	51 G. Scorpii	6 5	11 34	126	12 38	255	1 04
Aug. 4	30 Piscium	4.7	8 52	31	9 36	284	0 44
4	33 Piscium	4.7	10 20	45	11 20	262	1 00
4	24 B. Ceti	6.0	12 59	86	14 03	206	1 04
5	26 Ceti	6.0	13 30	20	14 28	271	0 58
5	33 Ceti	6.1	17 55	47	19 06	246	1 11
11	52 B. Geminorum	6.5	14 34	71	15 28	270	0 54
20	*l* Virginis	4.8	6 45	118	8 00	300	1 15
22	υ Libræ	5.3	10 11	160	10 49	232	0 38
29	143 B. Capricorni	6.1	8 02	83	9 14	240	1 12
29	154 B. Capricorni	6.1	13 07	61	14 16	242	1 09
30	69 Aquarii	5.6	11 07	91	12 11	206	1 04
30	τ Aquarii	4.4	12 27	58	13 40	237	1 13

COMET NOTES.

The Discovery of Comet 1909 *a*.—A few minutes before 2 A. M. on the morning of June 16, while sweeping with the 5¾ inch comet seeker I found a hazy object in the field with α Trianguli. After some delay the 9½ inch telescope

was turned upon it, but by the time motion was evident, twilight had begun and made it impossible to secure measures with the micrometer. The following night I had some difficulty in finding the comet owing to hazy sky. A few minutes after it was located clouds intervened and prevented micrometric measures.

This comet is round, except for a slight elongation away from the Sun. It is somewhat condensed toward the center, and has a faint nucleus. Its brightness is between that of an eighth and ninth magnitude star.

ZACCHEUS DANIEL.

Princeton University Observatory,
Princeton, New Jersey,
June 22, 1909.

New Comet *a* 1909 (Daniel).—The first new comet for this year was discovered by Zaccheus Daniel at Princeton on the night of June 15. The new comet is small, but rather bright in a small telescope, about 2′ in diameter, with a strong central condensation. With the 16 inch telescope on the morning of June 19, the observer occasionally glimpsed a very small stellar nucleus and could by averted vision and motion of the telescope catch glimpses of a very faint spreading tail extending 4′ or 5′ from the nucleus.

The discovery position of the comet was in the constellation Triangulum. It motion is northward more than a degree per day, and will carry the comet through the foot of Andromeda and head of Perseus.

The following observations are at hand :

	α			δ			Observer	Place
	h	m	s	°	′	″		
June 15.80	1	39	54	+28	55		Daniel	Princeton
16.5306	1	41	54.1	+29	58	18	Javelle	Nice
17.7888	1	45	24.7	+31	46	29	Hussey	Ann Arbor
18.7979	1	48	17.7	+33	11	17	Hussey	Ann Arbor
18.8204	1	48	21.7	+33	13	02	Miss Bigelow	Northampton
18.8441	1	48	35.18	+33	15	41.4	Wilson	Northfield
18.9809	1	48	49.5	+33	26	15	Tomas?	Mt. Hamilton

The following approximate elements and ephemeris computed by Kobold have been received by cable from Kiel, Germany. They depend upon observations made on June 16, 17 and 18.

ELEMENTS OF COMET *a* 1909.

$T = 1909$ June 5.31
$\omega = 5° 04′$
$\Omega = 305\ 21$
$i = 51\ 54$
$q = 0.842$

EPHEMERIS.

	R. A.	Decl.	Brightness
June 22	$1^h\ 59^m\ 23^s$	+38° 01′	0.80
26	2 12 36	+42 50	
30	2 26 59	+47 09	
July 4	2 42 32	+50 59	0.50

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

SY Androm.

d	h
July 6	2
Aug. 9	23

SX Cassiop.

July 7	14
13	4

U Cephei

July 2	1
7	1
12	0
17	0
22	0
26	23
31	23
Aug. 5	22
10	22
15	22
20	21
25	21
30	21

Z Persei

July 3	13
9	16
15	18
21	21
28	0
Aug. 3	3
9	5
15	8
21	11
27	13

RY Persei

July 3	7
17	1
30	18
Aug. 13	12
27	5

RZ Cassiop.

July 1	17
4	3
6	12
8	21
11	7
13	16
16	2
18	11
20	20
23	6
25	15
28	0
30	10
Aug. 1	19

RZ Cassiop.

d	h
Aug. 4	5
6	14
8	23
11	9
13	18
16	3
18	13
20	22
23	8
25	17
28	2
30	12

RX Cephei

July 24	23
Aug. 26	6

ST Persei

July 2	6
7	13
12	20
18	3
23	10
28	17
Aug. 3	0
8	7
10	23
16	6
21	12
24	4
29	12

Algol

July 2	23
8	17
14	9
20	4
25	21
31	15
Aug. 6	9
12	2
17	20
23	14
29	7

RT Persei

July 1	9
3	2
4	18
6	11
8	4
9	21
11	14
13	6
14	23

RT Persei

d	h
July 16	16
17	12
19	5
20	22
22	15
24	7
26	0
27	17
29	10
31	2
Aug. 1	19
3	12
5	5
6	22
8	14
10	7
12	0
13	17
15	9
17	2
18	19
20	12
22	4
23	21
25	14
27	7
29	0
30	16

λ Tauri

July 2	16
10	14
18	11
26	9
Aug. 3	7
11	5
19	2
27	0

RW Tauri

July 3	12
9	1
14	13
20	2
25	15
31	4
Aug. 5	17
11	6
16	19
22	8
27	21

RV Persei

July 1	10
5	9

RV Persei

d	h
July 9	7
13	6
17	5
21	4
25	2
29	1
Aug. 2	0
5	22
9	21
13	20
17	19
21	17
25	16
29	15

RR Persei

July 12	6
Aug. 7	15

RS Cephei

July 6	6
31	22
Aug. 24	22

RY Aurigæ

July 2	3
7	14
13	1
18	12
23	23
29	10
Aug. 3	21
9	8
14	19
20	6
25	16
31	3

RZ Aurigæ

July 1	19
7	20
13	21
19	22
25	22
31	23
Aug. 7	0
13	1
19	1
25	2
31	3

RW Geminorum

Aug. 1	11
7	4
12	22
18	15
24	9
30	2

U Columbæ

d	h
Aug. 2	0
7	15
13	5
18	19
24	10
30	0

RW Monoc.

Aug. 2	4
6	9
10	5
14	0
17	20
21	16
25	11
29	7

RX Geminorum

Aug. 12	15
24	20

RU Monoc.

Aug. 1	13
3	8
5	3
6	22
8	17
10	12
12	7
14	2
15	21
17	16
19	11
21	6
23	1
24	20
26	15
28	10
30	5

RX Geminorum

Aug. 7	20
26	11

R Canis Maj.

Aug. 1	13
3	20
6	2
8	9
10	16
12	22
15	5
17	11
19	18
22	0
24	7
26	13

Minima of Variable Stars of the Algol Type.—Continued.

R Canis Maj.

	d	h
Aug.	28	20
	31	1

Y Camelop.

July	3	8
	9	23
	16	13
	23	4
	29	19
Aug.	5	9
	12	0
	18	15
	25	5
	31	20

RR Puppis

Aug.	7	2
	19	23

V Puppis

Aug.	1	16
	4	14
	7	12
	10	10
	13	8
	16	5
	19	3
	22	1
	24	23
	27	21
	30	18

X Carinæ

July	1	21
	4	1
	6	5
	8	9
	10	13
	12	17
	14	21
	17	1
	19	5
	21	9
	23	13
	25	17
	27	21
	30	1
Aug.	1	5
	3	9
	5	13
	7	17
	9	21
	12	0
	14	4
	16	8
	18	12
	20	16
	22	20
	25	0
	27	4
	29	8
	31	12

S Cancri

	d	h
Aug.	9	3
	28	2

Y Leonis

July	1	12
	4	20
	8	5
	11	14
	14	23
	18	8
	21	17
	25	2
	28	11
	31	20

S Velorum

July	4	7
	16	4
	28	1

RR Velorum

July	1	4
	4	21
	8	14
	12	7
	16	0
	19	17
	23	10
	27	3
	30	20

SS Cancri

July	2	22
	9	13
	16	3
	22	18
	29	8

RW Urs. Maj.

July	1	3
	15	19
	30	11
Aug.	14	2
	28	18

Z Draconis

July	1	2
	3	19
	6	12
	9	5
	11	22
	14	16
	17	9
	20	2
	22	19
	25	12
	28	5
	30	23
Aug.	2	16
	5	9
	8	2
	10	19

Z Draconis

Aug.	13	12
	16	5
	18	23
	21	16
	24	9
	27	2
	29	19

SS Centauri

July	1	22
	6	21
	11	20
	16	19
	21	18
	26	17
	31	16
Aug.	5	15
	10	14
	15	13
	20	12
	25	11
	30	10

δ Libræ

July	2	21
	7	13
	12	5
	16	21
	21	12
	26	4
	30	20
Aug.	4	11
	9	3
	13	19
	18	11
	23	2
	27	18

U Coronæ

July	3	9
	10	6
	17	4
	24	2
	31	0
Aug	6	21
	13	19
	20	17
	27	14

115.1908 Ophi.

July	1	4
	6	2
	10	23
	15	20
	20	18
	25	15
	30	13
Aug.	4	10
	9	7
	14	5
	19	2
	24	0
	28	21

116.1908 Ophi.

	d	h
July	2	4
	6	6
	10	9
	14	12
	18	15
	22	18
	26	21
	31	20
Aug.	4	3
	8	6
	12	9
	16	12
	20	15
	24	18
	28	21

R Aræ

July	2	4
	11	0
	19	21
	28	17
Aug.	6	14
	15	10
	24	6

U Ophiuchi

July	1	17
	3	10
	5	2
	6	18
	8	10
	10	3
	11	19
	13	11
	15	3
	16	20
	18	12
	20	4
	21	20
	23	13
	25	5
	26	21
	28	13
	30	6
	31	22
Aug.	2	14
	4	7
	5	23
	7	15
	9	7
	10	23
	12	16
	14	8
	16	0
	17	17
	19	9
	21	1
	22	17
	24	10
	26	2
	27	18
	29	10

U Ophiuchi

	d	h
Aug.	31	3

Z Herculis

July	4	13
	12	13
	20	12
	28	12
Aug.	5	12
	13	11
	21	11
	27	5

RS Sagittarii

July	1	15
	6	11
	11	6
	16	2
	20	22
	25	18
	30	14
Aug.	4	10
	9	6
	14	2
	18	22
	23	18
	28	14

V Serpentis

July	3	8
	10	6
	17	3
	24	1
	30	23
Aug.	6	21
	13	19
	20	16
	27	14

RZ Draconis

July	1	16
	3	20
	6	1
	8	6
	10	11
	12	16
	14	21
	17	2
	19	7
	21	12
	23	16
	25	21
	28	2
	30	7
Aug.	1	12
	3	17
	5	22
	8	3
	10	8
	12	12
	14	17
	16	22
	19	3
	21	8
	23	13

Minima of Variable Stars of the Algol Type.—Continued.

RZ Draconis

	d	h
Aug.	25	18
	27	23
	30	3

RX Herculis

	d	h
July	1	4
	2	23
	4	18
	6	12
	8	7
	10	2
	11	20
	13	15
	15	10
	17	4
	18	23
	20	18
	22	13
	24	7
	26	2
	27	21
	29	15
	31	10
Aug.	2	5
	3	23
	5	18
	7	13
	9	7
	11	2
	12	21
	14	15
	16	10
	18	5
	19	23
	21	18
	23	13
	25	8
	27	2
	28	21
	30	16

SX Sagittarii

	d	h
July	2	10
	6	14
	10	18
	14	21
	19	1
	23	5
	27	9
	31	12

SX Sagittarii

	d	h
Aug.	4	16
	8	20
	12	23
	17	3
	21	7
	25	10
	29	14

RR Draconis

	d	h
July	2	8
	8	0
	13	16
	18	8
	24	0
	29	16
Aug.	4	8
	10	0
	15	16
	21	7
	26	23

RZ Ophiuchi

	d	h
July	19	5

U Scuti

	d	h
July	1	19
	3	17
	5	15
	7	13
	9	11
	11	9
	13	6
	15	4
	17	2
	19	0
	20	22
	22	20
	24	18
	26	15
	28	13
	30	11
Aug.	1	9
	3	7
	5	5
	7	2
	9	0
	10	22
	12	20
	14	18
	16	16
	18	13
	20	11

U Scuti

	d	h
Aug.	22	9
	24	7
	26	5
	27	4
	28	3
	29	2
	30	0
	30	23
	31	22

RX Draconis

	d	h
July	1	4
	4	23
	8	19
	12	14
	16	8
	20	3
	23	22
	27	17
	31	11
Aug.	4	6
	8	1
	11	20
	15	15
	19	10
	23	5
	27	0
	30	19

RV Lyræ

	d	h
July	2	15
	9	20
	16	0
	23	5
	31	10
Aug.	7	14
	14	19
	22	0
	29	5

U Sagittae

	d	h
July	1	10
	8	4
	14	23
	21	17
	28	11
	4	5
	11	0
	17	18
	24	12
	31	6

SY Cygni

	d	h
July	6	18
	18	19
	30	19
Aug.	11	19
	23	20

W Cygni

	d	h
July	2	21
	9	12
	16	3
	22	19
	29	10
Aug.	5	1
	11	16
	18	8
	24	23
	31	14

SW Cygni

	d	h
July	3	3
	12	6
	21	10
	30	13
Aug.	8	17
	17	20
	27	0

VW Cygni

	d	h
July	1	23
	18	20
Aug.	4	17
	21	13

UW Cygni

	d	h
July	1	6
	8	3
	15	0
	21	23
	28	20
Aug.	4	18
	11	16
	18	13
	25	11

W Delphini

	d	h
July	3	3
	12	18
	22	8
	31	23
Aug.	10	14
	20	4
	29	19

RR Delphini

	d	h
July	3	13
	12	18
	21	23
	31	4
Aug.	9	8
	18	13
	27	18

VV Cygni

	d	h
July	1	3
	4	2
	7	1
	10	0
	12	23
	15	22
	18	21
	21	20
	24	19
	27	18
	30	16
Aug.	2	15
	5	14
	8	13
	11	12
	14	11
	17	10
	20	9
	23	8
	26	6
	29	5

UZ Cygni

	d	h
July	10	10
Aug.	10	18

143.1907 Andr.

	d	h
July	2	2
	7	15
	13	4
	18	16
	24	5
	29	18
Aug.	4	6
	9	19
	15	8
	20	20
	26	9
	29	4

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SY Cassiop.

	d	h
July	1	13
	5	15
	9	17
	13	19
	17	20
	21	22
	26	0
	30	1
Aug.	3	3
	7	5
	11	6
	15	8
	19	10
	23	12
	27	13
	31	15

RW Cassiop.

(−5 19)

July	10	2
	24	22
Aug.	8	17
	23	12

RX Aurigæ

(−4 0)

July	1	22
	13	13
	25	5
Aug.	5	20
	17	11
	29	2

Y Aurigæ

(−0 18)

July	4	10
	8	6
	12	3
	16	0
	19	20
	23	17
	27	13
	31	10
Aug.	4	7
	8	3
	12	0
	15	20
	19	17
	23	14
	27	10
	31	7

T Monoc.

(−9 23)

July	5	15
Aug.	1	15
	28	16

W Geminorum

	d	h
	(−2	2)
July	2	22
	10	20
	18	18
	26	16
Aug.	3	14
	11	12
	19	10
	27	8

ζ Geminorum

(−5 0)

July	1	12
	11	16
	21	19
	31	23
Aug.	11	3
	21	7
	31	10

RU Camelop.

(−9 12)

July	22	19
Aug.	14	2

V Carinæ

(−2 4)

July	6	20
	13	13
	20	6
	26	22
Aug.	2	15
	9	8
	16	0
	22	17
	29	10

T Velorum

(−1 10)

July	4	22
	9	13
	14	4
	18	20
	23	11
	28	2
Aug.	1	18
	6	9
	11	0
	15	16
	20	7
	24	22
	29	14

W Carinæ

(−1 0)

July	4	3
	8	12
	12	21

W Carinae

	d	h
July	17	6
	21	15
	26	0
	30	9
Aug.	3	18
	8	2
	12	11
	16	20
	21	5
	25	14
	29	23

S Muscæ

July	8	1
	17	17
	27	9
Aug.	6	0
	15	16
	25	8

T Crucis

(−2 2)

July	7	10
	14	3
	20	21
	27	14
Aug.	3	8
	10	2
	16	19
	23	13
	30	6

R Crucis

(−1 10)

July	5	4
	11	0
	16	20
	22	16
	28	11
Aug.	3	7
	9	3
	14	23
	20	19
	26	14

S Crucis

(−1 12)

July	4	18
	9	10
	14	3
	18	20
	23	12
	28	5
Aug.	1	21
	6	14
	11	6
	15	23

S Crucis

Aug.	20	16
	25	8
	30	1

RZ Centauri

July	1	15
	3	12
	5	9
	7	6
	9	3
	11	0
	12	21
	14	18
	16	15
	18	12
	20	9
	22	6
	24	3
	26	0
	27	21
	29	18
	31	15
Aug.	2	12
	4	9
	6	6
	8	3
	10	0
	11	21
	13	18
	15	16
	17	13
	19	10
	21	7
	23	4
	25	1
	26	22
	28	19
	30	16

W Virginis

(−8 5)

July	6	1
	23	7
Aug.	9	14
	26	21

V Centauri

(−1 11)

July	4	5
	9	17
	15	4
	20	16
	26	4
	31	16

V Centauri

	d	h
Aug.	6	4
	11	16
	17	4
	22	15
	28	3

R Triang. Austr.

(−1 0)

July	1	0
	4	10
	7	19
	11	4
	14	14
	17	23
	21	8
	24	18
	28	3
	31	12
Aug.	3	22
	7	7
	10	16
	14	2
	17	11
	20	20
	24	6
	27	15
	31	0

S Triang. Austr.

July	6	19
	13	3
	19	11
	25	18
Aug.	1	2
	7	10
	13	18
	20	1
	26	9

S Normæ

(−4 10)

July	3	14
	13	8
	23	2
Aug.	1	20
	11	14
	21	8
	31	2

RV Scorpii

(−1 10)

July	5	15
	11	16
	17	18
	23	19
	29	21

Maxima of Variable Stars of Short Period not of the Algol Type.-Con.

RV Scorpii	d	h
Aug.	4	22
	11	0
	17	1
	23	3
	29	4

RV Ophiuchi Minimum.	d	h
July	4	14
	8	7
	11	23
	15	16
	19	8
	23	0
	26	17
	30	9
Aug.	3	2
	6	18
	10	11
	14	3
	17	20
	21	12
	25	5
	28	21

X Sagittarii	d	h
	(−2	22)
July	2	19
	9	19
	16	19
	23	19
	30	20
Aug.	6	20
	13	20
	20	21
	27	21

Y Ophiuchi	d	h
	(−6	5)
July	16	10
Aug.	2	13
	19	16

W Sagittarii	d	h
	(−3	0)
July	6	8
	13	22
	21	12
	29	3
Aug.	5	17
	13	7
	20	21
	28	12

Y Sagittarii	d	h
	(−2	2)
July	6	14
	12	8
	18	3
	23	21
	29	16
Aug.	4	10
	10	5
	16	0
	21	18
	27	13

U Sagittarii	d	h
	(−2	23)
July	1	14
	8	8
	15	2
	21	20
	28	14
Aug.	4	8
	11	1
	17	19
	24	13
	31	7

β Lyræ	d	h
	(−3	2)
	(−3	7)
July	5	22
	12	14
	18	20
	25	12
	31	18

κ Pavonis	d	h
	(−4	7)
July	5	8
	14	10
	23	12
Aug.	1	14
	10	16
	19	18
	28	21

U Aquilæ	d	h
	(−2	4)
July	5	14
	12	15
	19	15
	26	16
Aug.	2	16
	9	17
	16	18
	23	18
	30	19

U Vulpeculæ	d	h
	(−2	3)
July	5	13
	13	12
	21	12
	29	11
Aug.	6	11
	14	11
	22	10
	30	10

SU Cygni	d	h
	(−1	7)
July	2	16
	6	13
	10	9
	14	5
	18	2
	21	22
	25	18
	29	14
Aug.	2	11
	6	7
	10	3

SU Cygni	d	h
Aug.	14	0
	17	20
	21	16
	25	13
	29	9

η Aquilae	d	h
	(−2	6)
July	6	8
	13	13
	20	17
	27	21
Aug.	4	1
	11	5
	18	10
	25	14

S Sagittae	d	h
	(−3	10)
July	1	23
	10	9
	18	18
	27	3
Aug.	4	12
	12	21
	21	7
	29	16

X Vulpeculæ	d	h
	(−2	1)
July	6	2
	12	10
	18	18
	25	1
	31	9
Aug.	6	16
	13	0
	19	8
	25	15
	31	23

V Vulpeculae Minimum	d	h
July	1	21
	8	16

X Cygni	d	h
	(−6	19)
July	10	8
	26	18
Aug.	12	3
	28	12

T Vulpeculae	d	h
	(−1	10)
July	1	22
	6	8
	10	19
	15	5
	19	16
	24	2
	28	13
Aug.	1	23
	6	9
	10	20
	15	6
	19	17
	24	3

T Vulpeculae	d	h
Aug.	28	14

TX Cygni	d	h
July	12	19
	27	13
Aug.	11	6
	26	0

VY Cygni	d	h
	(−2	14)
July	4	23
	12	19
	20	16
	28	13
Aug.	5	9
	13	6
	21	2
	28	23

VZ Cygni	d	h
	(−2	12)
	(−3	6)
July	1	23
	6	23
	11	17
	16	17
	21	10
	26	10
	31	4
Aug.	5	4
	9	21
	14	21
	19	14
	24	14
	29	8

Y Lacertae	d	h
	(−1	10)
July	3	19
	8	3
	12	10
	16	18
	21	2
	25	9
	29	17
Aug.	3	0
	7	8
	11	15
	15	23
	20	6
	24	14
	28	22

δ Cephei	d	h
July	2	8
	7	17
	13	1
	18	10
	23	19
	29	4
Aug.	3	13
	8	21
	14	6
	19	15
	25	0
	30	9

V Lacertae	d	h
	(−1	16)
July	2	10
	7	10
	12	9
	17	9
	22	9
	27	8
Aug.	1	8
	6	7
	11	7
	16	6
	21	6
	26	6
	31	5

X Lacertae	d	h
July	2	2
	7	18
	13	5
	18	15
	24	2
	29	21
Aug.	3	23
	9	10
	14	20
	20	7
	25	17
	31	4

SW Cassiop.	d	h
July	2	10
	7	23
	13	12
	19	1
	24	14
	30	3
Aug.	4	16
	10	4
	15	17
	21	6
	26	19

RS Cassiop.	d	h
	(−1	19)
July	3	3
	9	10
	15	17
	22	0
	28	7
Aug.	3	14
	9	22
	16	5
	22	12
	28	19

RY Cassiop.	d	h
	(−7	10)
July	7	21
	20	1
Aug.	1	4
	13	8
	25	11

Approximate Magnitudes of Variable Stars on June 1, 1909.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R.A. 1900. h m	Decl. 1900. ° ′	Magn.
S. Sculpt.	0 10.3	−32 36	9.0	U Can. Min.	7 35.9	+ 8 37	8.5
X Androm.	10.8	+46 27	10.5	S Gemin.	37.0	+23 41	12.5*d*
T Cassiop.	17.8	+55 14	11.5*d*	T Gemin.	43.3	+23 59	12.5
Y Cephei	31.3	+79 48	12.0	U Puppis	56.1	−12 34	<13
U Cassiop.	40.8	+47 43	<14	R Cancri	8 11.0	+12 2	9.0 *i*
W Cassiop.	49.0	+58 1	11.5*d*	V Cancri	16.0	+17 36	7.8
S Cassiop.	1 12.3	+72 5	14.0*d*	U Cancri	30.0	+19 14	13.5*d*
R Sculpt.	22.4	−33 4	6.0	X Urs. Maj.	33.7	+50 30	11.0 *i*
RS Sculpt.	22.5	−33 26	<12.5	S Hydrae	48.4	+ 3 27	9.0 *i*
X Cassiop.	49.8	+58 46	9.0	T Hydrae	50.8	− 8 46	13.0
U Persei	53.0	+54 20	9.2*d*	T Cancri	51.0	+20 14	10.0*d*
Z Cephei	2 12.8	+81 13	10.8	S Pyxidis	9 0.7	−24 41	11.2*d*
S Persei	15.7	+58 8	9.5	W Cancri	4.0	+25 39	13.5
RR Cephei	30 4	+80 42	12.0 *i*	R Carinae	29.7	−62 21	9.9*d*
R Trianguli	31.0	+33 50	12.0*d*	X Hydrae	30.7	−14 15	10.5 *i*
R Horologii	50.6	−50 18	7.0*d*	Y Draconis	31.1	+78 18	10.0*d*
Y Persei	3 20.9	+43 50	10.5	R Leo. Min.	39.6	+34 58	12.5*d*
R Persei	23 7	+35 20	13.5	RR Hydrae	40.4	−23 34	<13.5
U Eridani	46.2	−25 16	9.5 *i*	R Leonis	42.2	+11 54	9.0 *i*
T Eridani	51.0	−24 20	11.5*d*	Y Hydrae	46.4	−22 33	7.0
W Eridani	4 7.3	−25 24	<12	V Leonis	54.5	+21 44	13.1*d*
R Tauri	22.8	+ 9 56	8.5 *i*	RR Carinae	54.8	−58 23	7.5
W Tauri	22.2	+15 49	12.3	S Carinae	10 6.2	−61 4	8.5
S Tauri	23.7	+ 9 44	11*d*	Z Carinae	10.4	−58 12	<12
T Camelop.	30.4	+65 57	9.1*d*	R Urs. Maj.	37.6	+69 18	7.0
R Reticuli	32.5	−63 14	10.5*d*	V Hydrae	46.8	−20 43	10.5*d*
X Camelop.	32.6	+74 56	12.8*d*	W Leonis	48.4	+14 15	9.2 *i*
R Doradus	35.6	−62 16	6.3	S Leonis	11 5.7	+ 6 0	13.0*d*
R Caeli	37.0	−38 26	8.8	R Comae	59.1	+19 20	12.5 *i*
R Pictoris	43.5	−49 26	7.5	T Virginis	12 9.5	− 5 29	13.3
V Tauri	46.2	+17 22	<12.5	R Corvi	14.4	−18 42	9.0*d*
R Orionis	53.6	+ 7 59	12.5*d*	SS Virginis	20.1	+ 1 19	8.4*d*
V Orionis	5 0.8	+ 3 58	8.5	T Can. Ven.	25.2	+32 3	9.3
T Leporis	0.6	−22 2	12.0	Y Virginis	28.7	− 3 52	10.5 *i*
R Aurigae	9.2	+53 28	9.5*d*	U Centauri	28.0	−54 6	<12
W Aurigae	20.1	+36 49	<14	T Urs. Maj.	31.8	+60 2	8.3 *i*
S Aurigae	20.5	+34 4	11.0*d*	R Virginis	33.4	+ 7 32	10.4*d*
S Camelop.	30.2	+68 45	8.5	RS Urs. Maj.	34.4	+59 2	12.0
U Aurigae	35.6	+31 59	12.8	S Urs. Maj.	39.6	+61 38	8.0
R Columbae	46.7	−29 13	10.5*d*	RU Virginis	42.2	+ 4 42	10.5 *i*
U Orionis	49.9	+20 10	6.5 *i*	U Virginis	46.0	+ 6 6	8.5 *i*
V Camelop.	49.4	+74 30	13*d*	RT Virginis	57.6	+ 5 43	9.0*d*
R Octantis	56.4	−86 26	10.5	RV Virginis	13 2.7	−12 38	10.0
Z Aurigae	53.6	+53 18	10.5	V Virginis	22.6	− 2 39	10.0 *i*
W Aurigae	6 16.5	+47 45	9.7	R Hydrae	24.2	−27 46	9.1
V Monoc.	17.2	− 2 9	11.0	S Virginis	27.8	− 6 41	12.5
S Lyncis	35.9	+58 0	9.9 *i*	T Urs. Min.	32.6	+73 56	12.8
X Gemin.	40.7	+30 23	8.5 *i*	T Centauri	36.0	− 3 36	6.0
Y Monoc.	51.3	+11 22	13.5	R Can. Ven.	44.6	+40 2	11.7 *i*
X Monoc.	52.4	− 8 56	9.8*d*	RR Virginis	59.6	− 8 43	<13
R Lyncis	53.0	+55 28	13.5	Z Bootis	14 1.7	+13 59	13.0
R Gemin.	7 1.3	+22 52	13.6	R Centauri	9.4	−59 27	8.0
R Can. Min.	3.2	+10 11	9.8*d*	U Urs. Min.	15.1	+67 15	11.0 *i*
L^2 Puppis	10.5	−44 29	5.0	S Bootis	19.5	+54 16	13.1*d*
RR Monoc.	12.4	+ 1 17	<14	R Camelop.	25.1	+84 17	12.9
V Gemin.	17.6	+13 17	<13	R Bootis	32.8	+27 10	11.6*d*
S Can. Min.	27.3	+ 8 32	8.0 *i*	V Librae	34.8	−17 14	13.0
Z Puppis	28.3	−20 27	<12	S Lupi	46.8	−46 12	8.5

Approximate Magnitudes of Variable Stars on June 1, 1909—Con.

Name.	R. A. 1900.	Decl. 1900.	Magn.	Name.	R. A. 1900.	Decl. 1900.	Magn.
	h m	° ′			h m	° ′	
U Bootis	14 49.7	+18 6	11.5	R Pavonis	18 3.3	−63 38	12.5
RT Librae	15 0.8	−18 21	12.5*d*	T Herculis	5.3	+31 0	9.4*d*
T Librae	5.0	−19 38	12.6	RY Ophiuchi	11.6	+ 3 40	11.0*d*
Y Librae	6.4	− 5 38	9.8*d*	W Lyrae	11.5	+36 38	12.8*d*
S Librae	15.6	−20 2	12.0*d*	RV Sagittarii	21.4	−33 23	12.8*d*
S Serpentis	17.0	+14 40	11.8	SV Herculis	22.3	+24 58	12.8*d*
S Coronae	17.3	+31 44	9.6*d*	T Serpentis	23.9	+ 6 14	12.5
RS Librae	18.5	−22 33	10.0*d*	RZ Herculis	32.7	+25 58	10.5 *i*
RU Librae	27.7	−14 59	9.2	X Ophiuchi	33.6	+ 8 44	6.4
X Librae	30.4	−20 50	11.0	RY Lyrae	41.2	+34 34	<13
S Urs. Min.	33.4	+78 58	8.6*d*	RW Lyrae	42.1	+43 32	<13
U Librae	36.2	−20 52	11.8*d*	RX Lyrae	50.4	+32 42	12.3
Z Librae	40.7	−20 49	12.7*d*	S Coron. Aust.	54.4	−37 5	12.8*d*
R Coronae	44.4	+28 28	13.0	ST Sagittarii	55.9	−12 54	13.0
X Coronae	45.2	+36 35	10.0*d*	R Coron. Aust.	55.2	−37 6	12.0
R Serpentis	46.1	+15 26	7.7 *i*	T Coron. Aust.	55.2	−37 6	13.0
V Coronae	46.0	+39 52	9.0	Z Lyrae	56.0	+34 49	11.5*d*
R Librae	47.9	−15 56	<13	RT Lyrae	57.8	+37 22	9.8
R Lupi	47.0	−36 0	<12	R Aquilae	19 1.6	+ 8 5	10.8
RR Librae	50.6	−18 1	11.0 *i*	V Lyrae	5.2	+29 30	<13
Z Coronae	52.2	+29 32	10.0 *i*	RX Sagittarii	8.7	−18 59	11.0
RZ Scorpii	58.6	−23 50	9.7 *i*	RW Sagittarii	8.1	−19 2	9.4
Z Scorpii	16 0.1	−21 28	9.0 *i*	S Lyrae	9.1	+25 50	13.0*d*
R Herculis	1.7	+18 38	12.2*d*	RS Lyrae	9.3	+33 15	<13
RR Herculis	1.5	+50 46	8.5	RU Lyrae	9.1	+41 8	<13
U Serpentis	2.5	+10 12	12.8	U Draconis	9.9	+67 7	11.0
X Scorpii	2.7	−21 16	12.8	W Aquilae	10.0	− 7 13	13.1
W Scorpii	5.9	−19 53	12.7	T Sagittarii	10.5	−17 9	10.8
RX Scorpii	5.9	−24 38	10.5 *i*	R Sagittarii	10.8	−19 29	10.0*d*
RU Herculis	6.0	+25 20	<13	RY Sagittarii	10.0	−33 42	7.5
R Scorpii	11.7	−22 42	<13	S Sagittarii	13.6	−19 12	<13
S Scorpii	11.7	−22 39	12.8*d*	Z Sagittarii	13.8	−21 7	12.2
W Coronae	11.8	+38 3	8.8	U Lyrae	16.6	+37 42	10.3
W Ophiuchi	16.0	− 7 28	<13	T Sagittae	17.2	+17 28	9.5
V Ophiuchi	21.2	−12 12	9.0	TY Cygni	29.8	+28 6	11.4
U Herculis	21.4	+19 7	12.0	RT Aquilae	33.3	+11 30	10.0*d*
Y Scorpii	23.8	−19 13	<12.5	R Cygni	34.1	+49 58	9.3 *i*
SS Herculis	28.0	+ 7 3	8.8	RV Aquilae	35.9	+ 9 42	<13
T Ophiuchi	28.0	−15 55	11.6*d*	T Pavonis	39.5	−72 1	8.0
S Ophiuchi	28.5	−16 57	10.2 *i*	RT Cygni	40.8	+48 32	9.2 *i*
W Herculis	31.7	+37 32	8.2 *i*	TU Cygni	43.3	+48 49	12.8
R Draconis	32.4	+66 58	10.7 *i*	χ Cygni	46.7	+32 40	4.5
RR Ophiuchi	43.2	−19 17	<13	S Pavonis	46.8	−59 27	7.0
S Herculis	47.4	+15 7	11.0 *i*	RR Sagittarii	49.7	−29 27	8.0*d*
RS Scorpii	48.4	−44 56	11	RU Sagittarii	51.8	−42 7	8.5*d*
RR Scorpii	50.2	−30 25	11.0*d*	RR Aquilae	52.4	− 2 11	9.2
RV Herculis	56.8	+31 22	10.3 *i*	RS Aquilae	53.7	− 8 9	<13
RT Scorpii	56.8	−36 47	<11	Z Cygni	58.6	+49 46	9.0 *i*
R Ophiuchi	17 2.0	−15 58	12.8 *i*	R Capricorni	20 5.7	−14 34	<12.5
RT Herculis	6.8	+27 11	13.0*d*	R Telescopii	7.6	−47 16	<13
RW Scorpii	8.3	−33 19	10.5 *i*	W Capricorni	8.6	−22 17	13.5
Z Ophiuchi	14.5	+ 1 37	10.5 *i*	Z Aquilae	9.8	− 6 27	12.8
RS Herculis	17.5	+23 1	11.2*d*	RT Sagittarii	11.1	−39 25	9.5 *i*
S Octantis	25.9	−86 46	12.5	U Cygni	16.5	+47 35	7.8 *i*
RU Ophiuchi	28.5	+ 9 30	13.0*d*	R Microscopii	34.0	−29 9	<12
RU Scorpii	35.1	−43 42	11.3*d*	S Indi	49.0	−54 42	<13
RS Ophiuchi	44.8	− 6 40	11.3	V Capric.	21 1.8	−24 19	<12.5
RT Ophiuchi	51.8	+11 11	<13	T Cephei	8.2	+68 5	6.7 *i*
T Draconis	54.8	+58 14	12.5	S Cephei	36.5	+78 10	9.2 *i*
— Draconis	54.8	+58 13	11.0	R Gruis	42.1	−47 22	12.0*d*
RY Herculis	55.4	+19 29	9.0	R Pisc. Aust.	22 12.3	−30 6	<13

Approximate Magnitudes of Variable Stars on June 1, 1909—Con.

Name.	R. A. 1900.		Decl. 1900.		Magn.	Name.	R. A 1900		Decl. 1900		Magn.
	h	m	°	′			h	m	°	′	
X Aquarii	22	13.2	−21	24	10.5*d*	S Aquarii	22	51.8	−20	53	13
RT Aquarii		17.7	−22	34	9.0 *i*	RR Cassiop.	23	50.7	+53	8	9.8
T Gruis		19.9	−38	4	8.5 *i*	R Tucanae		52.2	−65	57	<13
S Gruis		19.9	−48	57	11.8	R Casssiop.		53.3	+50	50	12.5
R Indi		28.9	−67	48	9.0 *i*	Y Cassiop.		58.2	+55	7	9.5

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Mt. Mt. Holyoke, Whitin, Swartz, and Harvard Observatories, including the South African Station of the latter observatory.

New Variable Stars 7. and 8.1909.—In *A. N.* 4320 Professor W. Ceraski calls attention to two new variable stars discovered by Mme. L. Ceraski upon the Moscow photographs. Their positions are

	α 1855	δ 1855	α 1900.0	δ 1900.0
7.1909 Geminorum	6h 04m 54s	δ +27° 43′	6h 07m 44s	+27° 43′
8.1909 Trianguli	2 18 37	+32 05	2 21 17	+32 17

From an examination of twenty-three plates obtained between 1895 and 1909 it appears that 7.1909 varies between magnitudes 10 and 12½, and that the period is probably several months. The discussion of fourteen plates obtained from 1906 to 1909 indicates that 9.1909 varies between magnitudes 10 and 11½, the period being about 8½ months. The last maximum occurred in October, 1908.

New Variable 12.1909 Pegasi.—This is announced by Professor Ceraski in *A. N.* 4321. On fifteen photographs taken in the years 1906 to 1908, the variation indicated is between magnitudes 10 and 12. The period is probably long. The position of the star is

1855.0	α = 23h 29m 47s	δ = +31° 53′
1900.0	23 32 00	+32 08

New Variable 13.1909 Vulpeculæ.—In *A. N.* 4321 Mr. T. A. Astbury of Wallingford, England, asks observers to watch the star B.D. +22° 3617 (7.5m). The star has a normal brightness of about 7.9m on the Harvard scale, but upon Sept. 17 and Oct. 27, 1908 it appeared to gradually diminish in brightness to the extent of rather more than a half magnitude in an hour and forty minutes. The place of the star is

1900.0 α = 19h 07m.2 δ = +22° 15′.

New Variables 15. and 16.1909 Lacertæ.—These are announced by Professor W. Ceraski in *A. N.* 4322. The first has a range of variation of one magnitude, from 10m to 11m, and the period is either shortor quite irregular. The second varies from 10m to less than 12m in a period of roughly a year. The positions of the stars are

	α 1855	δ 1855	1900	δ 1900
15.1909 Lacertae	$22^h\ 38^m\ 27^s$	$+48°\ 59'$	$22^h\ 40^m\ 21^s$	$+49°\ 13'$
16.1909 Lacertae	22 50 01	+47 42	22 52 00	+47 56

New Variable 17.1909 Draconis.—In *A. N.* 4321, Professor Wolf calls attention to the star B.D. +58°1782, which is ordinarily of magnitude 9.0, but upon a photograph taken on May 8, 1909, $9^h\ 18^m - 10^h\ 53^m$, Königstuhl mean time, was of about the 11th magnitude. Photographs taken on April 22 and May 9 show the star at magnitude 9.

Variable Star Notes.

U AURIGAE

1908 November 3, 9.2 Magnitude
November 11, 8.7 Magnitude
December 10, 10.5 Magnitude
December 14, 11 Magnitude
December 16, 11.5 Magnitude
December 28 Invisible

The above estimates are founded on the magnitudes of the comparison stars used in POPULAR ASTRONOMY, January 1899, page 43.

SS CYGNI

1908 August 23, 9:15—Of 11.9 magnitude.
August 24, 8:50—The same
August 26, 8:40—The same
August 28, 8-45—The same
August 29, 8:40—Between *c* and *d* or of 10 magnitude
September 9, 8:12—About 9.2 magnitude

The comparsion stars used are those in POPULAR ASTRONOMY, September 1897, page 272.

U GEMINORUM

On 27 evenings distributed between the 8th of January and the 11th of March 1908, this irregular variable was invisible in a four inch lens. Past seven was the hour of observation. The stars lettered on the excellent chart in POPULAR ASTRONOMY for May, 1897, page 19, were used for comparison during a recent maximum observed as follows :

1909 January 28, 30 —Invisible *F* of 11.2 magnitude also invisible. Moonlight
February 15, 16, 18, 20 —Invisible. *F* and *h* visible
February 22, 25 —Invisible
March 10, 7:15 —Equal to *b*, less than *a*
March 11, 12, 7:15 —The same
March 14, 16, 7:15 —Less than *b*, equal to *e*, brighter than *F*
March 17, 7:15 —Less than *e*, brighter than *F*

U HERCULIS

Maxima of this star, whose period is about thirteen months, were observed in 1906, from April 27th to May 20th, and in 1907, on the 8th and 9th of June. In 1908, it had not advanced beyond 10th magnitude on June 19th, and this present year just emerged from invisibility on the 13th of May, when it was barely discernible in a four inch lens.

V Boötis

Twelve observations of this variable, between the 13th of April and the 13th of May, showed a maximum of about 7th magnitude. On the latter date, no decrease was yet noticeable. Rose O'Halloran.

San Francisco, California.

GENERAL NOTES.

Ten Numbers a Year instead of one for each of the twelve months of the year seems to be a unending source of trouble to subscribers. We state again that Popular Astronomy is published monthly excepting two summer months. This number for June-July goes the last of June: the next number, that for August-September, will be mailed the last of August. We hope by reminding our readers of the above facts we shall save some scores of subscribers the trouble of sending in complaints of failure to receive an August number!

Times of Sunrise and Sunset in the U. S. In our note, in the last issue, upon the above entitled pamphlet of Professor Robert W. Wilson of Harvard University, we neglected to say that the book can be ordered from the publishers, Harvard Coöperative Society, price in paper covers, $1; stiff covers, $1.25.

Origin of Lunar Terrestrial System. You are authorized to make public the following cablegram sent from this Observatory to the *Astronomische Nachrichten* to-day:

"Have proved Lunar Terrestrial System originated by capture, and that Moon came to Earth from heavenly space.—See."

As this announcement will occasion general surprise even among astronomers, I will add that my proof of the capture of the satellites is based upon the methods of Hill, Poincaré and Darwin, and follows incontestably from the integral of Jacobi when the latter is properly corrected by the addition of a secular term to take account of the secular effects of the resisting medium formerly pervading our system (cf. *A.N.* 4308). It will be found that the proof, therefore, has all possible mathematical rigor, and the results admit of no dispute. Having applied the general method by which I have proved that the satellites as a class are captured to the case of the Earth and Moon, which is the only planetary subsystem admitting of any doubt, I find that the Moon, too, was captured.

As this result will require considerable revision of the previous teachings of science, it is evident that the problems of the physics of the Earth, and of geology, as well as of astronomy, will have to be re-examined from the ground up. Meanwhile I ask the scientific public to exercise sufficient patience to enable me to get the work out in a presentable manner. Most of these results were established in July, 1908, and were freely discussed with personal friends in November and December; but my severe illness in January, February and March delayed the progress of the investigation for over three months, and I have only recently been able to resume it.

Mare Island, Cal. T. J. J. See.

Spectroscopic Work at the Tacubaya Observatory. Two years ago at the suggestion of Professor Valle, director of this observatory, solar, spectroscopic observations were begun here. The instrument, a Grubb spectroscope, made for the 15-inch (380 mm.) equatorial, has four 60° prisms of heavy flint and one of double total reflection, and has a resolving power of nearly 13,000.

At first, observations were made on prominences noting the position, shape, size, and their general character. The lines used were C, F, and D_3. Later observations of sun-spot spectra were included and weakened, obliterated, strengthened, distorted, and reversed lines were registered.

Unfortunately this work could not be continued systematically on account of bad weather and the pressure of the principal work of the observatory; the astrographic chart.

Our observatory was invited to join in the work of the International Union for Solar Research and in order to participate more actively the Director ordered a spectroheliograph of Steinheil in München. The illustration gives a good idea of the instrument fitted on the equatorial. It is a fine piece of work notwithstanding some small defects. These, I hope, may soon be corrected in Europe.

The camera and collimator are of equal focal-length and of 25 mm. aperture. The ratio is 1:17. As the ratio of the object glass of the telescope is approximately 1:13 the collimator does not use the full light-gathering power of the objective. The dipersion train, composed of a mirror, a simple prism and a compound prism gives a total deviation of 180°. During the exposure the plate is stationary and the dipersion system with the collimator and camera and slits are driven by springs, the motion being controlled by oil clepsydrae.

In the present condition of the instrument the first slit does not close to uniform width producing non-uniformity of exposure on the negative. The second slit has the appropriate curvature, matching the first, and stands 5 mm. in front of the plate. On account of this excessively great distance, it is impossible to have the slit and spectrum line in focus at once even with the small magnification used, and it is difficult to set on the lines and wellnigh impossible beforehand to say what part of H or K is used. On account of the small size of the spectroheliograph, the Sun must be photographed in two or three parts in order to obtain a complete register of its surface.

The photographs reveal the flocculi very clearly and much fine detail over the surface. A comparison of our plates with those obtained at the Ebro Observatory at Roquetas in Spain is favorable to us. Our plates show more and finer details. However, our solar image has a diameter of 5 cm. while that of the Ebro is but 3 cm.

The solar observational program will include observations of prominences and chromosphere with the Grubb spectroscope, daily photographs with the Dallmeyer photoheliograph, and records of the calcium flocculi with the spectroheliograph, after the defects of this instrument are corrected.

The best hours for solar observations are in the early morning and near noon from 11 to 2 o'clock.

Tacubaya Observatory, Mexico, March, 1909. JOAQUIN GALLO.

New Astronomical Observatory at Dayton, Ohio. We notice by the papers that an amateur Astronomical Society has been formed at Dayton, Ohio, and that it is in the plans of the Society soon to build an observatory in the outskirts of the city.

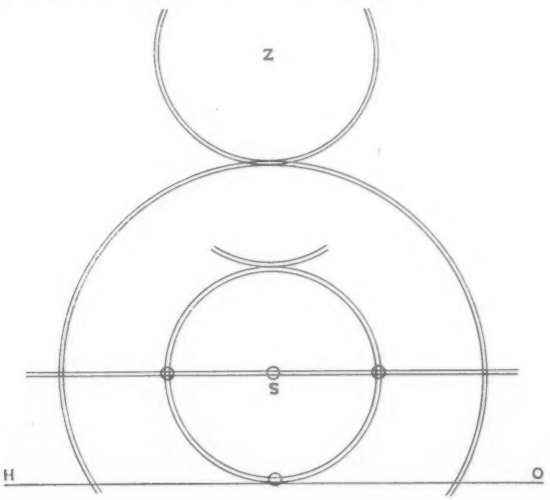
The president of the Society is Geo. R. Young, and the secretary is Perle L. Sagebill.

Observatory in South Chicago. The Chicago *Tribune* of May 23, contains a description of an observatory before unknown to us. It is a private observatory, owned by a Lithuanian priest by the name of Anton Petrajtis, and is near Eighty-ninth and Palmer streets. The object glass of the instrument is eleven inches in diameter, and the eye-pieces have the ordinary range for the size of the objective. The accessories are a photographic camera, a micrometer, and a telescope.

Mr. Petrajtis is a Russian and evidently much interested and in love with astronomy to do all that he is doing for that science in addition to the parish work, which claims, it is said, his first and best attention. His people love him greatly, and there is reason for it, when it is known that he delights to instruct the common and the uneducated people in the wonders of the heavens which he can so well do with a telescope as large as that he possesses.

Solar Halos, accompanied by parhelia, or sundogs, which are rarely seen in our latitude, have been witnessed at Wellesley, latitude 42° 17′ 42″, a number of times this winter. The finest displays were the afternoons of February 24 and March 16.

February 24 about 5 P. M. (eastern time) the low Sun was surrounded by a rainbow circle which theory shows to be 22°.5 in radius. On this circle, right and left, were the sundogs or parhelia, bright with prismatic color, and just above the Sun was an arc of a tangent circle. At least a quadrant of a larger circle 45 degrees in diameter was seen. This display lasted until sunset when a white glow like a flash-light streaked vertically upward.



March 16 about 4:30 P. M., the Sun was again surrounded by the circle of 22°.5 radius, and attended right and left by prismatic parhelia, also the flash-light vertical streak appeared. But this time while there was nothing of the 45° circle, there was a circle which would have been tangent to it seen around the zenith in which the rainbow colors were very strong.

Several observers noted different mornings in March fragments of circles and prismatic parhelia attending the rising Sun.

I know of no such remarkable displays as these I have described above seen here for many years.

The best discussion, of which I know in English, of these complicated halos is in Hastings's treatise on Light. There a picture is given of a halo of complete development seen by Arctic explorers and the halos described above can be seen to be fragments of such a display.

It is there shown that phenomena of this sort are due to the refraction and total reflection of light by hosts of hexagonal ice crystals in the upper air, of either the plate form, or with longer axes. These crystals each consist of six sixty-degree prisms, and twelve right angled prisms formed by the relation of their sides, and they may lie in the air with their axes directed or undirected.

It can be seen from the drawing reproduced from Hastings that, when all conditions are favorable, a complete display includes a circle about the Sun of 22°.5 radius, another of 45° radius, a rainbow circle tangent to the second about the zenith as a center, a circle through the Sun parallel to the horizon on which are various parhelia, also a number of tangent arcs.

Whitin Observatory, SARAH F. WHITING.
Wellesley College.

Rev. Frederic Campbell, Sc. D., of Brooklyn, N. Y., has recently been re-elected to the office of President of the Department of Astronomy in the Brooklyn Institute of Arts and Sciences. Dr. Campbell is writing for the Institute Bulletin; he furnishes the science illustrations and astronomical articles for the *Boy's World*, and the daily astronomical items, together with a monthly survey, to a symdicate of papers through the American Press Association.

Cheltenham Magnetic Observatory. An interesting quarto volume of 205 pages has just come to hand from the Department of Coast and Geodetic Survey, giving the results of observations made at the Cheltenham Magnetic Observatory at Cheltenham, Maryland during 1901 to 1904, under the direction of O. H. Tittmann, superintendent, and by Daniel L. Hazard, computer in the division of terrestrial magnetism.

This report gives a full account of the Observatory and its surroundings, and the observational work done there during the peroid named above. The reproduction of the magnetograms showing the principal magnetic storms during 1902-1904, is a feature of general interest for any one who is desirous of making a comparison between the ordinary and the magnetic storms of this period.

Perrine's Preliminary Account of the Solar Parallax by Eros. C. D. Perrine of Lick Observatory has recently published a preliminary account of the solar parallax, in the Lick Observatory Bulletin, No. 150, derived from photographs of Eros, taken with the Crossley reflector in 1900 between Oct. 6 and Dec. 24. In describing this work, Mr. Perrine says :—

"Of the 965 plates obtained, 410 were selected for measurement and reduction. 129 of these taken near the meridian on 44 nights were used in determining the place of the asteroid and the correction to the ephemeris. The remaining 281 plates were exposed on 18 nights at as great hour angles as possible, for the determination of parallax. Out of about 1400 images of Eros and the comparison stars which these 281 negatives contain, only 823 were considered perfect enough for measurement. The observations are about equally divided between east and west hour angles. Only such plates as were obtained under favorable conditions have been used.

Besides Eros, from six to ten comparison stars were measured on each negative. The accurate positions of these comparison stars were obtained from the plates taken with the larger-field astrographic telescopes by other observers. These positions were very fully discussed by Professor Hinks of the Cambridge Observatory. His results were used as far as possible in the Crossley work. A few star places were deduced from the Crossley meridian plates. The plates were all measured on the Stackpole engine. Systematic errors in measurement and reduction were guarded against as far as possible.

Two systems of reduction were adopted. The first used the same stars for the east and west plates, to eliminate the effects of errors in the star places. The second used stars symmetrically situated about Eros, to eliminate possible distortions of the mirror, errors of refraction, aberration of the star images, etc.

The details of the measures and reductions will be published by the Carnegie Institution of Washington, which provided funds for this part of the work. Only the results will be given here. The slight differences between the results of so many combinations seem to make it unnecessary to go into further refinements of weighting and selection. If we take the simple mean of the four values derived respectively from all equations, all equations under 0.″050, all dates, all dates (October 13 revised), weighted by the square root, we find values which differ but slightly from those based on any of the other reasonable assumptions. I, therefore, consider the following as the most probable values of the solar parallax from the two solutions.

Solution 1	8″.80	+″.0070
Solution 2	8 .80	+ .0064

As there seems to be no good reason why one of these values should be given greater weight than the other, the simple mean is adopted as the final result, making the value of the solar parallax

$$\pi\odot = 8''.8067 \qquad \pm''.0025$$

The assigned probable error is not the result of any single assumption, but is estimated from the probable errors derived in several ways, as follows:

P. E., 126 equations	±″.0027
P. E., 96 equations	± .0018
P. E., 18 daily means	± .0052
P. E., 15 daily means (omitting largest 3 values)	± .0034
P. E., 8 results used in final combination	± .0018

Kustner's Catalogue of 10,663 Stars between 0° and 51° North Declination for 1900. The great bulk of the observations for this catalogue were made in the years 1894–1899; revision observations were, however, obtained when needed until 1903. The whole of the observations were made by Professor Küstner himself, and the instrument—the 6-inch Repsold Meridian Circle of the Bonn Observatory—remained unaltered during the comparatively

short time over which the observations extended. Seeing that the observations numbered something like 30,000, the task has been a prodigious one for a single individual to have accomplished in so limited a time; it must clearly have required an extraordinary degree of energy and devotion on the part of Professor Küstner. Rather more than 7,000 of the stars are contained in catalogues of the Astronomische Gesellschaft, and the hope is expressed that the present work may enable these catalogues to be compared more closely than has hitherto been possible with a uniform fundamental system.

Professor Küstner has investigated the effect of magnitude-equation both in right ascension and declination with great completeness. The effect is in part directly eliminated, since screens were used in observing the fundamental and other bright stars, in order to reduce them in the mean to magnitude 8.5; but in addition the magnitude equation both of the observer and of the fundamental catalogue (that of Auwers) was determined. Professor Küstner's magnitude-equation in right ascension proved to be very small; in declination it was considerably larger. The magnitudes of the stars were estimated at each observation, and, after all necessary corrections had been applied, reduced to the Potsdam scale. The resulting magnitudes are given in the catalogue.

In the case of double stars occurring in the catalogue, measures of the positions and magnitudes of the components were made with an equatorial, thus supplementing the meridian observations.

A. S. E. in *Monthly Notices*, February, 1909.

The Astrographic Chart and Catalogue. The annual report of this undertaking has now become little more than a statement of the publications issued during the year. At the beginning of 1908, volume ii. of the Greenwich Section was distributed, which completes the publication of the rectangular co-ordinates of the stars in the region from 64° N. to the Pole alloted to the Royal Observatory. The conversion of the co-ordinates into Right Ascension and Declination for such of these stars as have been previously observed and catalogued is proceeding. The fourth volume of the Oxford University Observatory Zone has been also published, containing 65,808 stars, which completes the publication of the measures of the stars from Dec. 32° N. to 27° N., and leaves two similar volumes to finish this section. A second volume, numbered Tome iii., containing all the stars between R.A. 6^h and 9^h in the zone Dec. 39° to 47° N., has been issued from the Helsingfors Observatory, which gives equatorial co-ordinates in the complete way explained when the first volume was published in 1904. From comparison of dates, an estimation may be made of the time required to complete the eight volumes, which will contain the catalogue of this zone. Neither Potsdam nor the French Observatories have published any instalments during the year, owing possibly to changes in the Directorships. The reports from the Cape and Melbourne show that the measuring of the stars in the South Pole region 41° to the South Pole is proceeding, and the formation of the catalogue for the remaining parts of the sky 47° to 64° N. Declination, and 3° to 41° S., is proceeding, it is believed, with more or less rapidity, but exact reports of the state of the work will no doubt be presented at the meeting of the Permanent Committee, which is to be held at Paris in April of this year.

The number of enlargements of chart plates distributed up to the end of December last is

Paris	331	San Fernando	165
Algiers	309	Tacubaya	61
Toulouse	158	Greenwich	934
Bordeaux	70		

H. P. H. in *Monthly Notices*, February, 1909.

Summer Observations at Toronto. Several phenomena witnessed recently may be of some interest to astronomical readers.

The eclipse of the Moon on June 3, was visible here, but through very foggy air. So cloudy was the air, that it was with difficulty the exact location of the Moon in the sky could be found. Eventually it did slightly emerge from the mists during the progress of the eclipse, when it appeared like the Moon four or five days old, but with the crescent lying reversed on the sky. Business prevented my following the course of the eclipse, but when I was at liberty, shortly after twelve o'clock, the "just past full" Moon shone with great brilliance on an almost unclouded sky.

On the evening of the 19th of May, 1909, Jupiter's satellites presented the interesting phenomena of being all to the west of the planet. Jupiter's satellites all appear at the one or other side of the planet at the same hour about three times a month. Jupiter seems to have been a little less clearly defined this year, than during other seasons. His belts are not difficult to observe, but features on the planet such as the exact shape of the belts, and the great red spot, have been quite beyond my observation. I have observed with a four inch refractor, and with a six inch and a fifteen inch reflector. Both of the latter are of my own construction. The fifteen inch I made this year, beginning to grind the mirror early in February.

The Moon in the fifteen inch is a wonderful sight. Something I had not seen before appeared when looking at the Moon through it. A grayish light appeared to project beyond the Moon's terminator, and this light was different from the sky or anything in the vicinity. I concluded that this light was the Sun falling on territory of the Moon beyond the regular terminator, and which territory was sufficiently hilly to permit of parts of its surface barely reaching the first touch of sunlight. An atmosphere on the Moon would have accounted for this appearance, but the existence of a lunar atmosphere is so universally denied that to suggest it is almost out of the question.

The lights and shadows on the Moon during its first quarter, were magnificently revealed with the fifteen inch reflector. I have powers for it up to about 650, but not much advantage is derived in going higher than about 300; and my own preference is for a considerably lower power than that,—about 200—being very satisfactory.

Last night the Sun at setting was as red as I ever remember seeing it. Its color was just about as red as the flower we call the bleeding heart. A curious illustration of the tricks played by the atmosphere was very noticeable. A cloud lay across the face of the Sun, dividing the upper two-thirds from the lower third. The division was in the form of a narrow band. But the lower third seemed to be a segment of a circle which lay a little farther above the horizon than the other two-thirds of the Sun. The fact that the two parts of the Sun did not form a complete circle where the narrow cloud belt removed was most apparent. Most likely atmospheric refraction was responsible for the phenomena.

To-day there is one very large sun-spot visible, and close to it a sizeable group is seen. The first of these—the large sun-spot,—is surrounded by a penumbra every part of which is as wide as the sun-spot itself. If the sun-spot be a cavity, and the penumbra be its sloping edges, these edges must be of great extent. In the outer extremity of the penumbra is a well defined sun-spot also.

ALBERT R. J. F. HASSARD.

Toronto, Canada,
June 7, 1909.

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[For particulars, write Prof. W. H. Pickering, Harvard Observatory, Cambridge, Massachusetts, U. S. A.]

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